

Data Analysis and Visualization

Introduction to Virtual Reality and Immersive Visualization

Benjamin Weyers

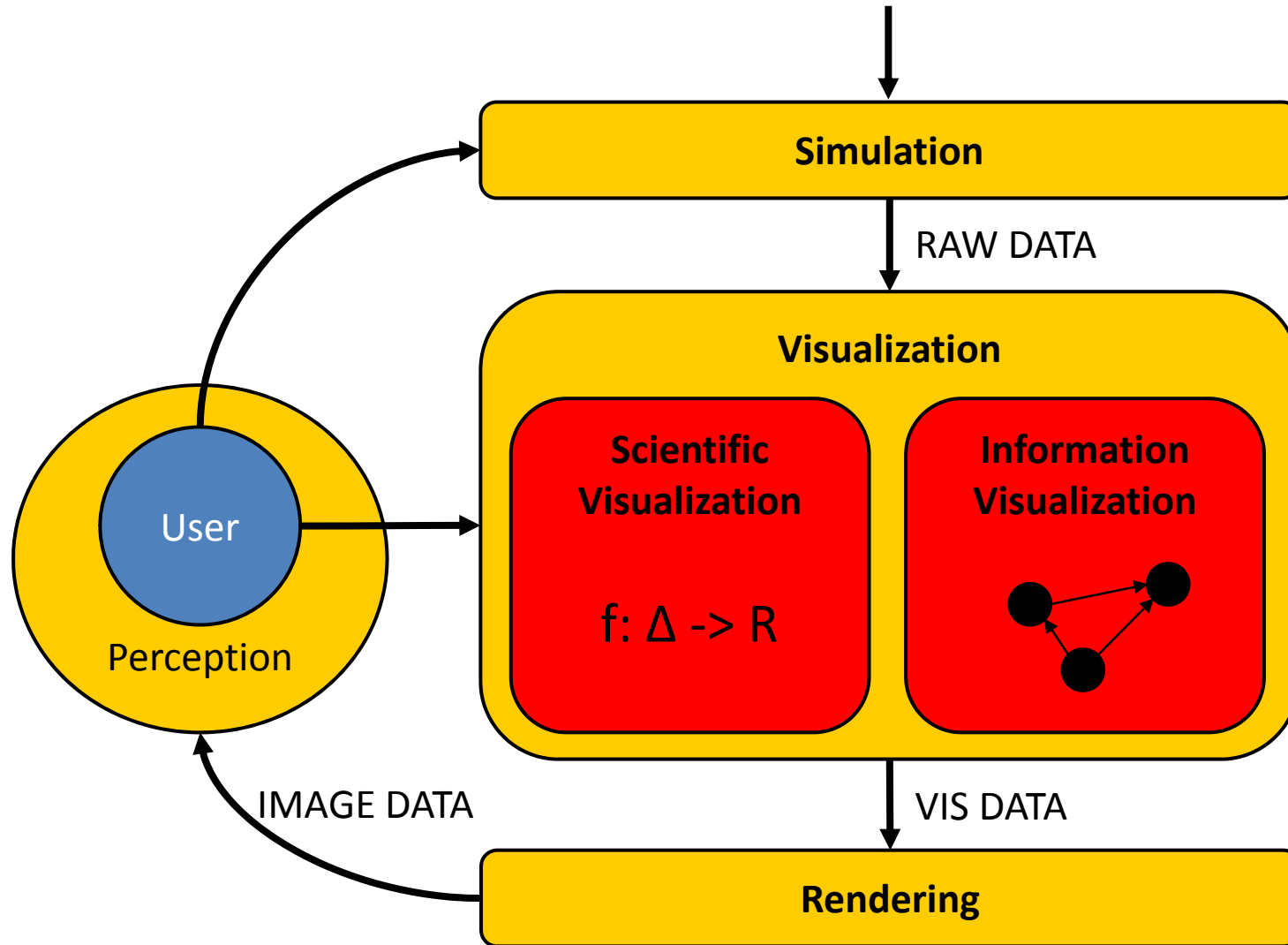
One Minute Paper – Positive Feedback

- Good Examples IIIIII (7)
- Clear English IIII (4)
- Good slides IIII (4)
- Humorous II (always tries (!) to make jokes) (2)
- Man kann alle Inhalte verstehen II (2)
- Really nice lecture II (2)
- Sum up at the end of each part
- Bester Vortrag seit 2 Jahren studieren, hat mich voll motiviert das Fach zu rocken. Freue mich auf Dezember 😊
- Folien sind sehr übersichtlich
- Interessante Vorlesung mit Selbstexperiment
- Gutes Tempo
- Good structure
- Viele Bilder
- Sehr interessant und anschaulich
- Science Applications

One Minute Paper –Negative Feedback

- Show real application examples (Google Cardboard, 3D Rendering software) III (3)
- Somewhat quiet III (3) -> *Microphone*
- Voice modulation helps to get human attention II (2)
- Nicht immer klar was wichtig / klausurrelevant ist II (2)
- Inhalte veraltet II (2)
- Nothing II (2)
- More programming exercise -> *Next Exercises on Web-based InfoVis*
- Include some assignment / project for rendering
- Formeln werden nicht erklärt
- Use MatLab to show operations
- Not going to deeply into topics
- Mathematical Notation: $v \cdot M$ bad, $M \cdot v$ good
- I didn't get the concept of the first two lectures
- Folien übersprungen
- Luminance and Brightness: Difference?
- Too long
- Vague objective of the course

Closer look to (Visual) Analysis in the Simulation Loop



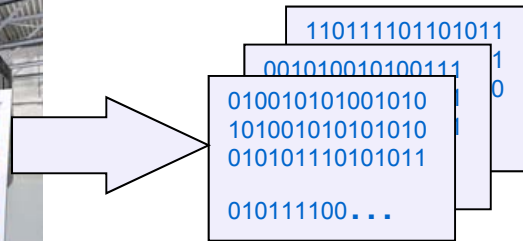
Introduction - Topics

- What is Virtual Reality?
- VR Displays and Systems
- Stereoscopic, Viewer-Centered Projections
- VR in Scientific Visualization

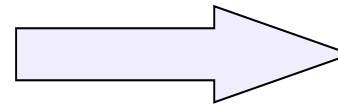
Why Data Analysis & Visualization?



JUQUEEN IBM Blue Gene/Q System, JSC,
Forschungszentrum Jülich GmbH



raw data
Gigabyte-Terabyte-Petabyte

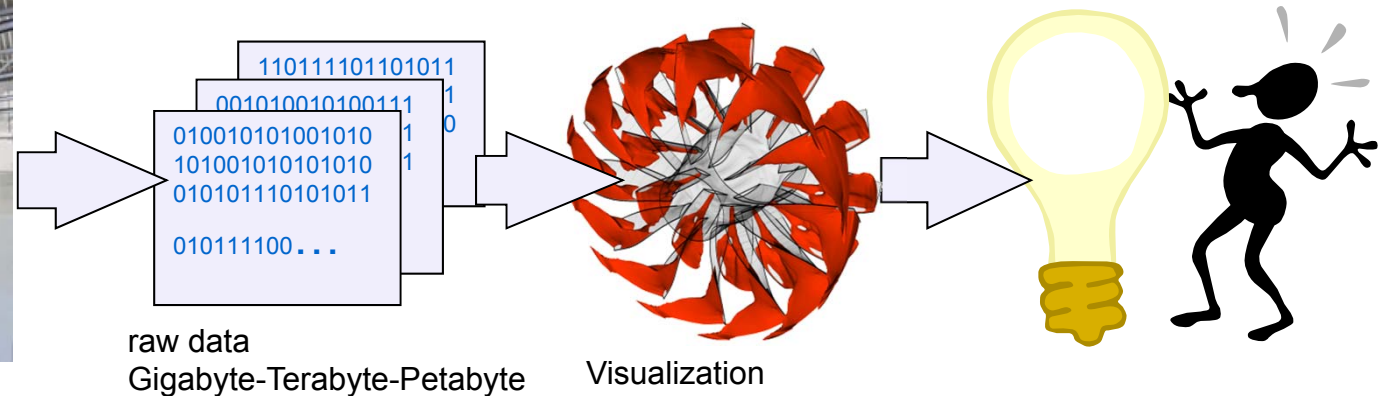


- Generating insight from data requires data analysis.
Hamming: „The purpose of Computing is insight, not numbers!“

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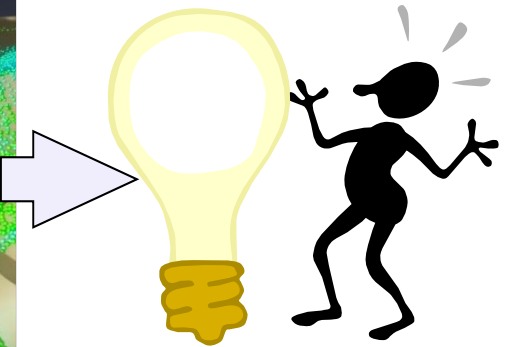
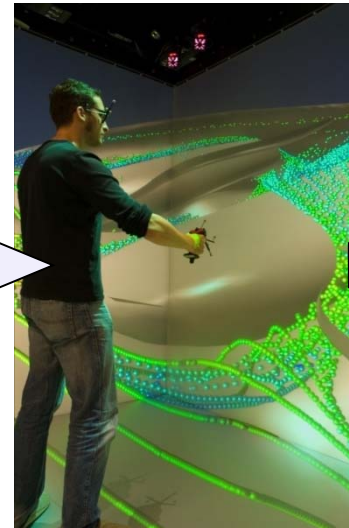
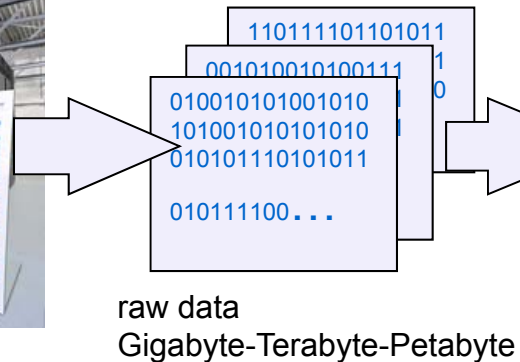
- Generating insight from data requires data analysis.
Hamming: „The purpose of Computing is insight, not numbers!“
- **Visualization** is (primarily) being used for the analysis process



Why Data Analysis & Visualization?



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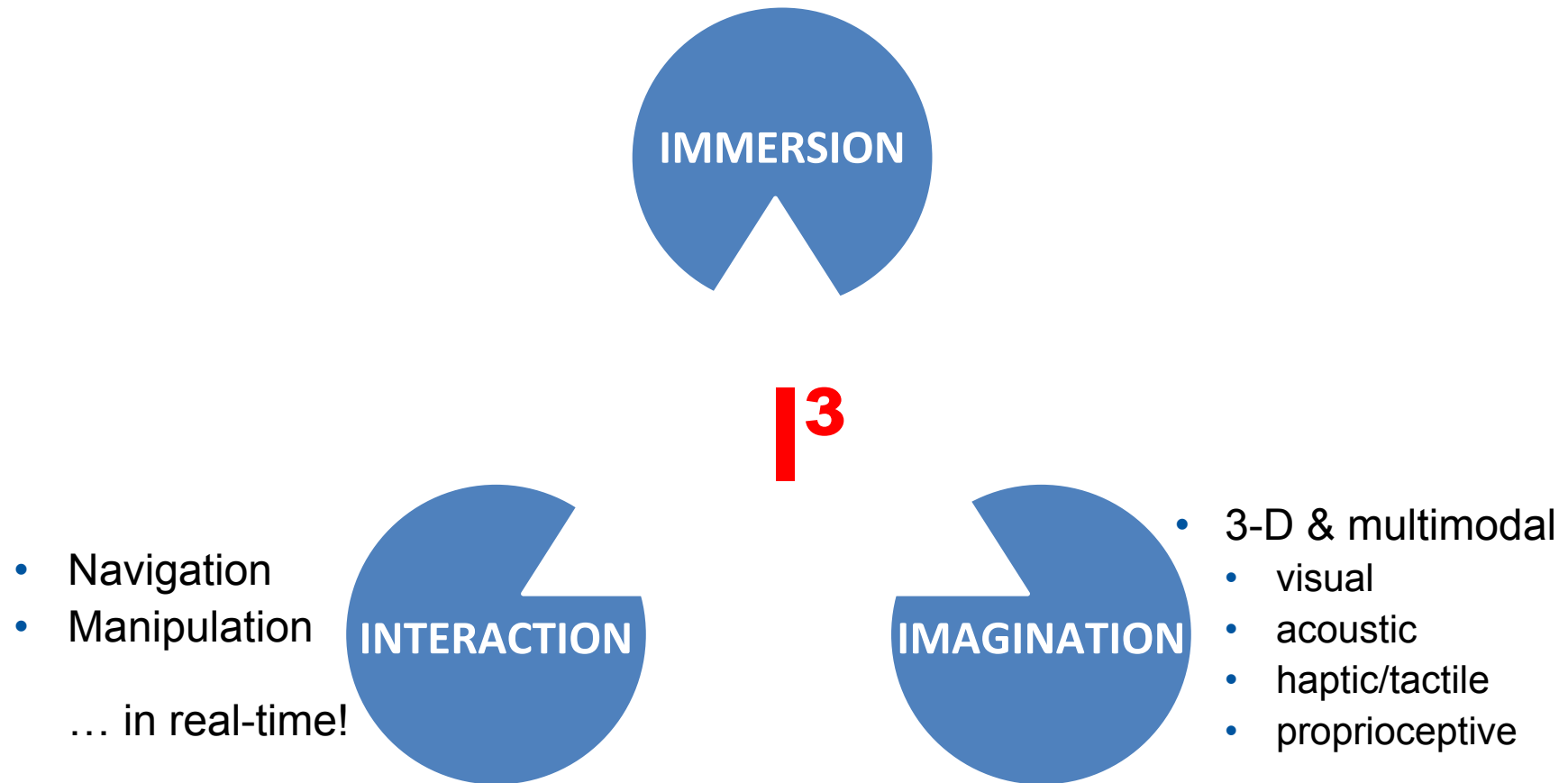
- Generating insight from data requires data analysis.
Hamming: „The purpose of Computing is insight, not numbers!“
- **Visualization** is (primarily) being used for the analysis process
- Amount of raw data is rapidly increasing: Finer grids, 3-D, time-variant
- Explorative versus confirmative analysis, **Virtual Reality**

Introduction – Topics

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Virtual Reality (VR) is a computer generated **environment**. A user can **interact** with this environment and experience it with her **natural senses**.

What is Virtual Reality about?



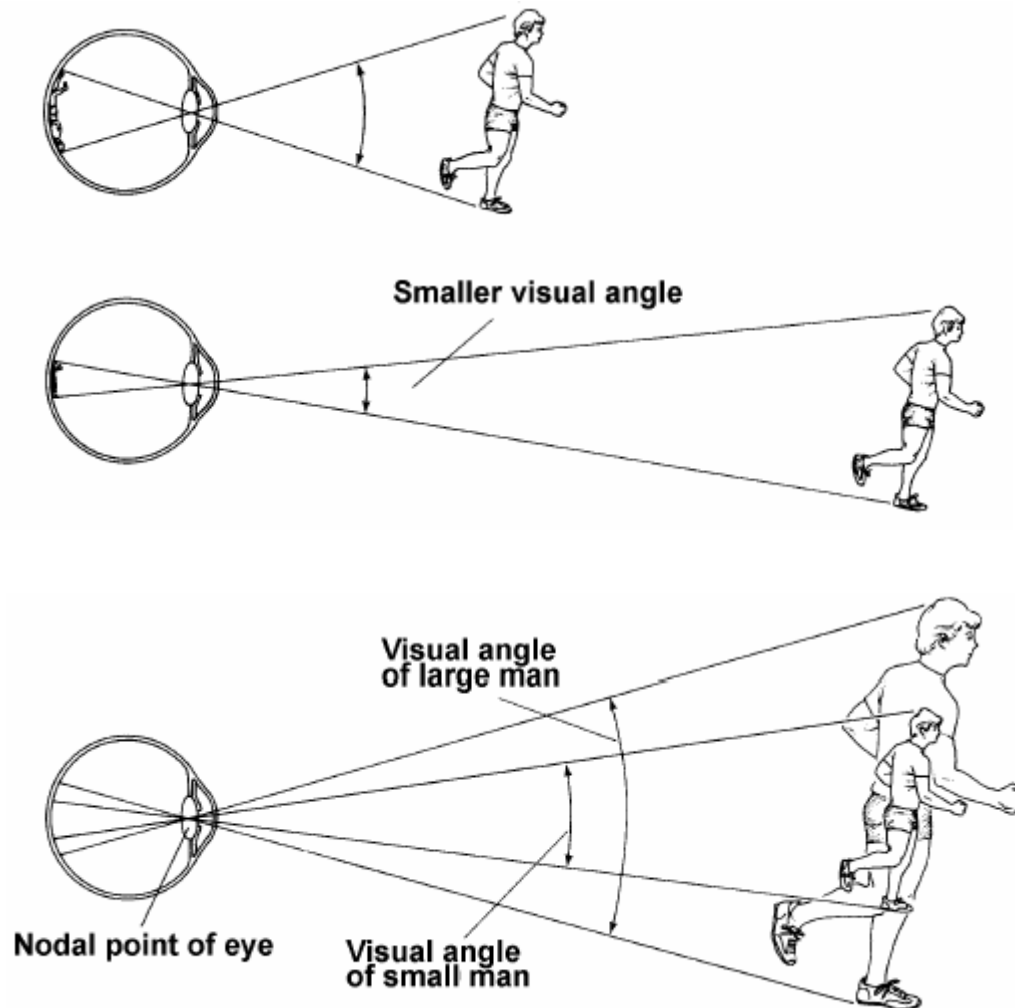
3D Vision: Physiological & Psychological Cues

Traditional **CG**:

- Psychological clues
 - Perspective shortening
 - Occlusion of objects
 - Light and shadows
 - Texture gradients
 - Atmospheric perspective

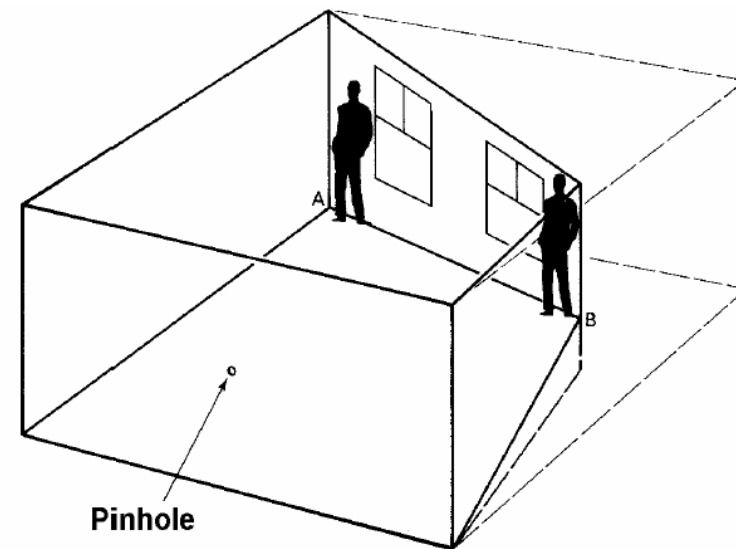
Perspective

Drawing: Goldstein (WWW)



The Ames Room

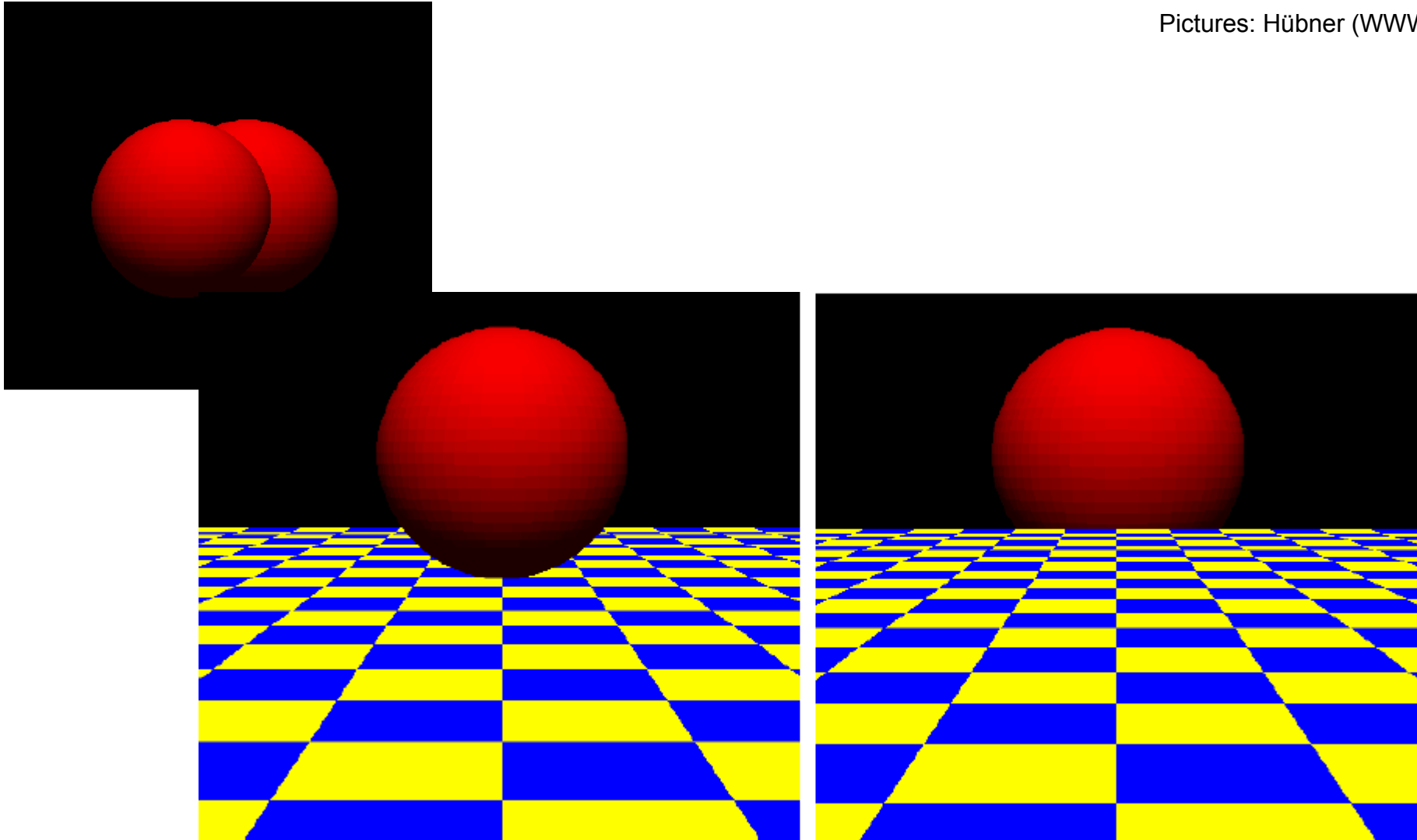
Pictures: Goldstein, Levine & Shefner (WWW)



https://upload.wikimedia.org/wikipedia/commons/1/11/Ames_room.ogv

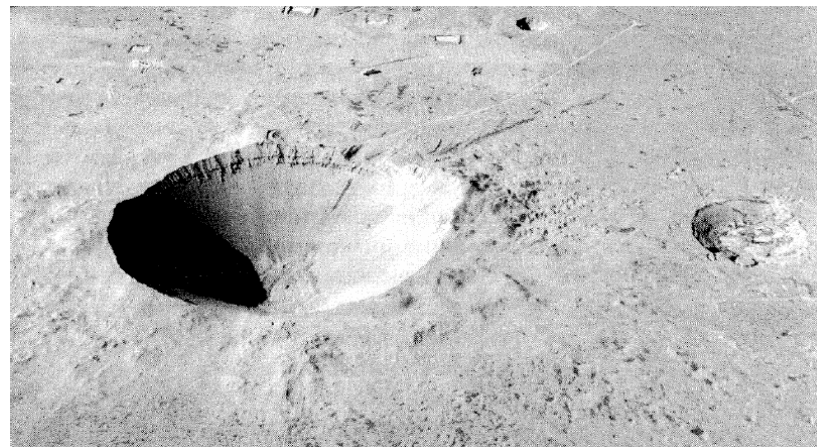
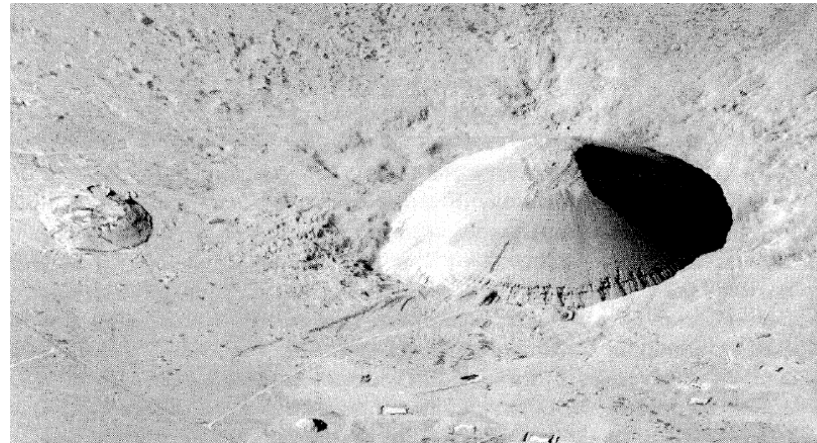
Occlusion

Pictures: Hübner (WWW)



Light & Shadows

Pictures: Levine & Shefner (WWW)



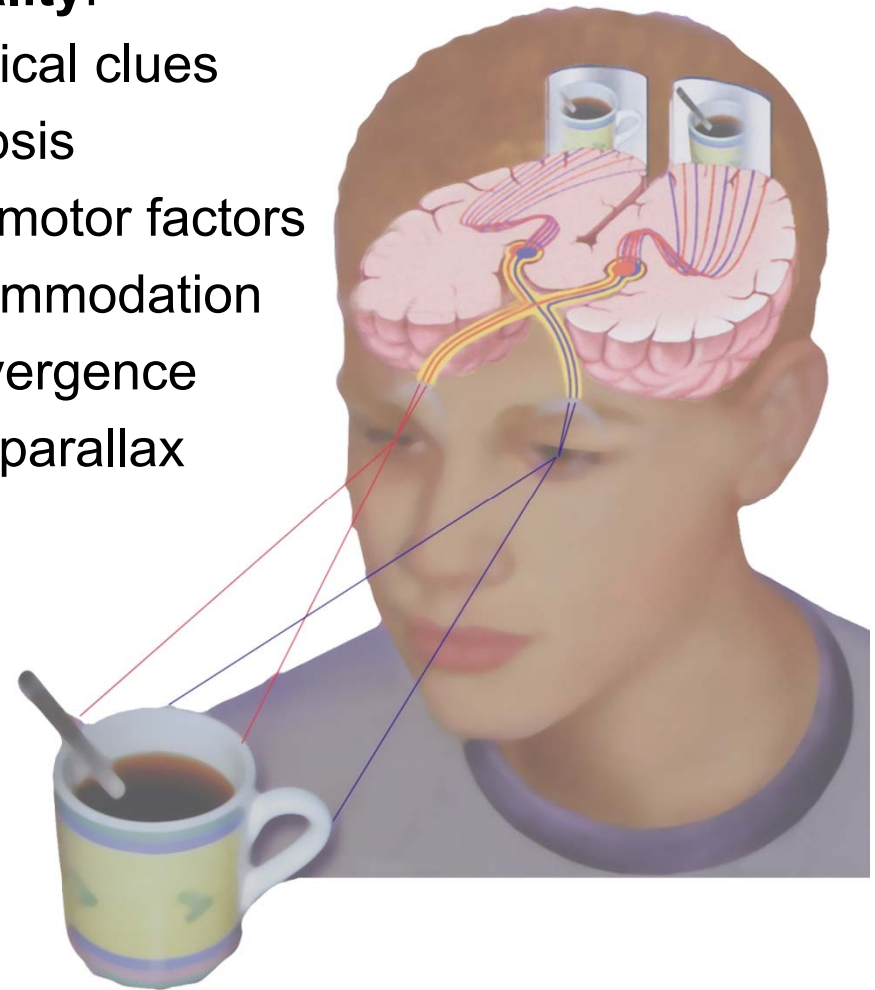
3D Vision: Physiological & Psychological Cues

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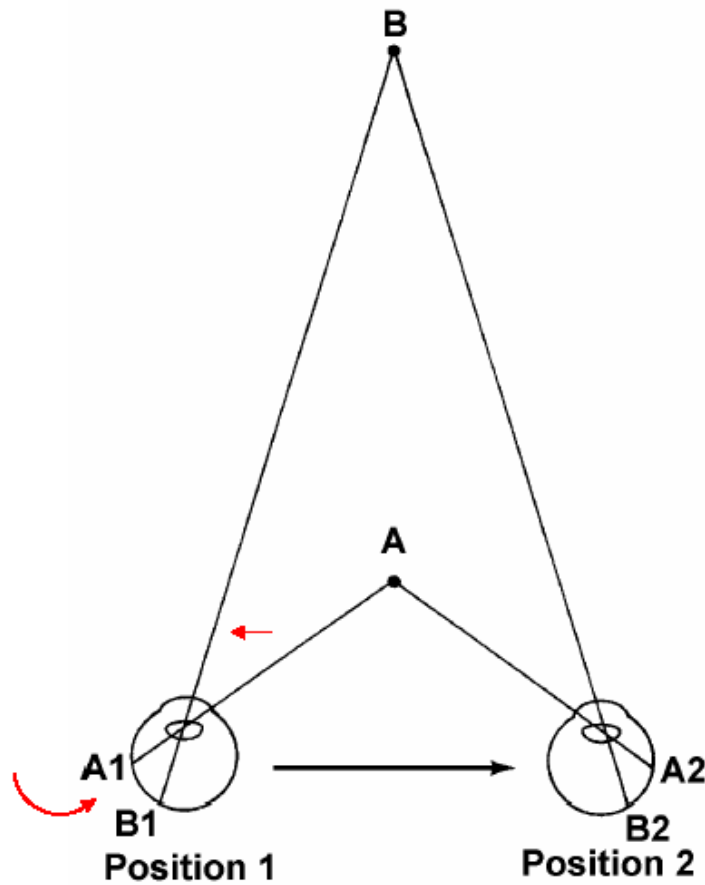
Virtual Reality:

- Physiological clues
 - Stereopsis
 - Ocular motor factors
 - Accommodation
 - Convergence
 - Motion parallax



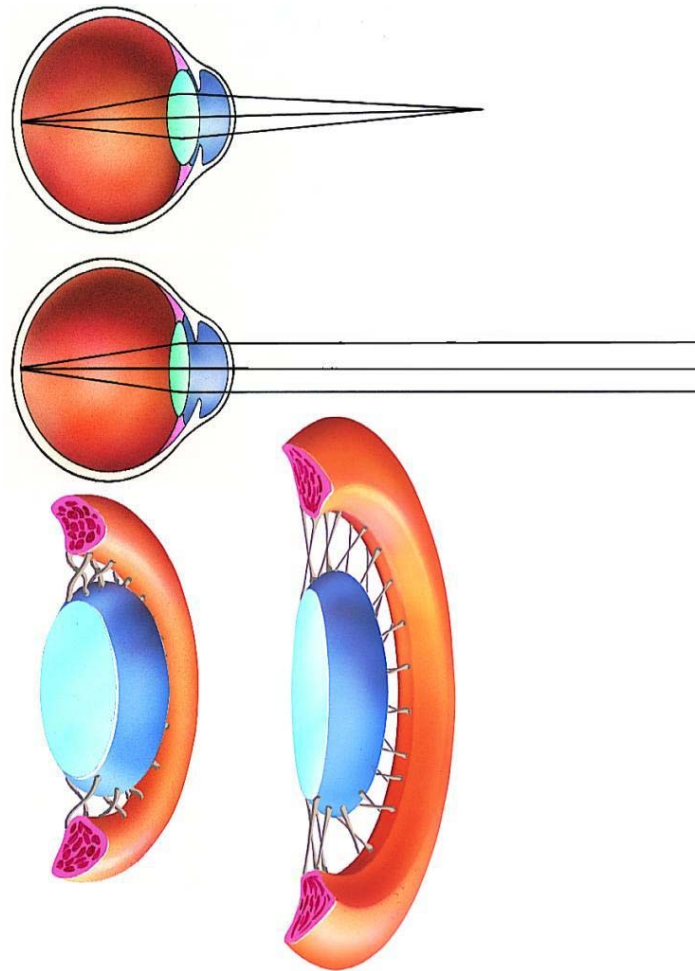
Convergence

Drawing: Goldstein (WWW)

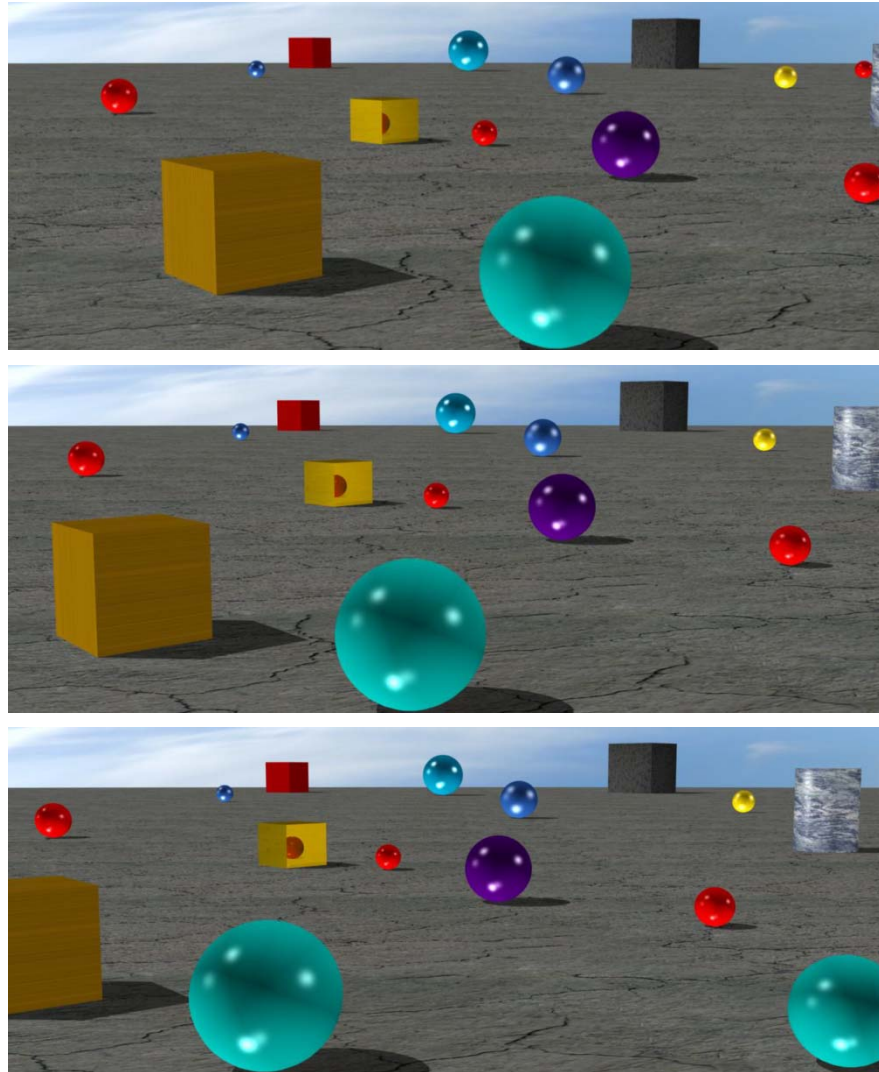


Accommodation

<http://www.denstoredanske.dk>

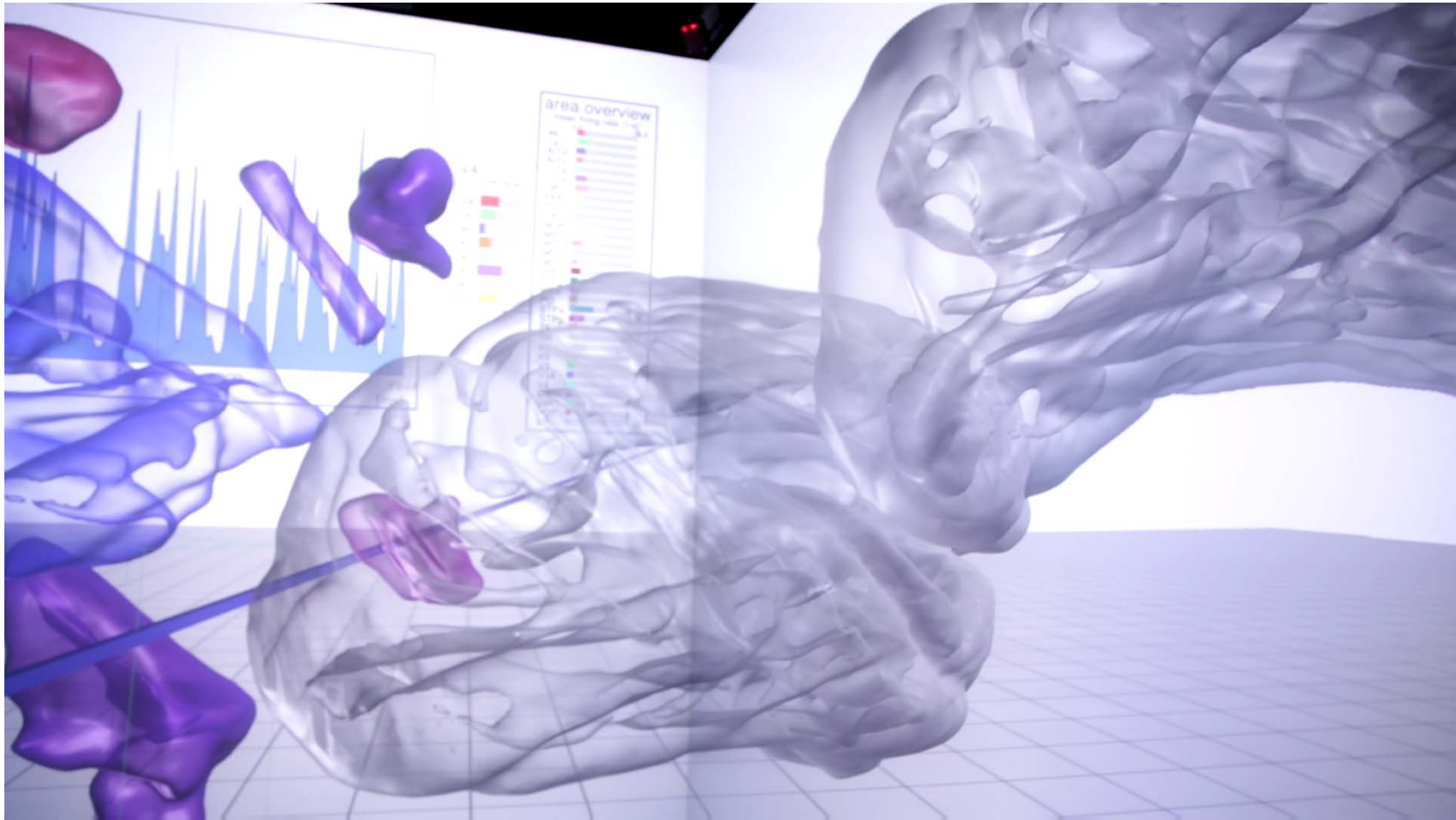


Motion Parallax



Tom Vaughan,
www.cyberlink.com

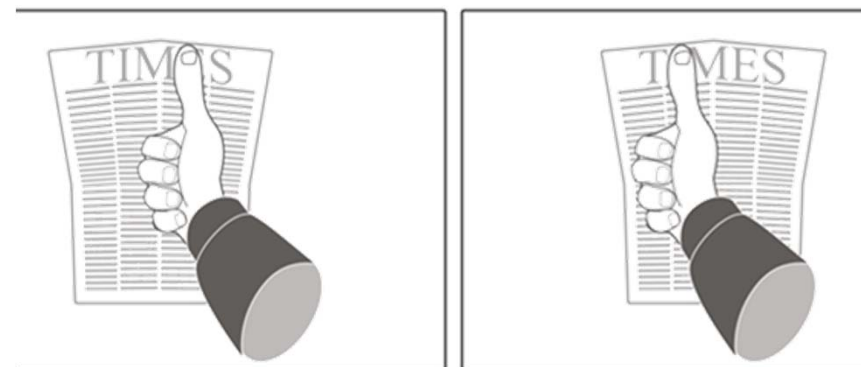
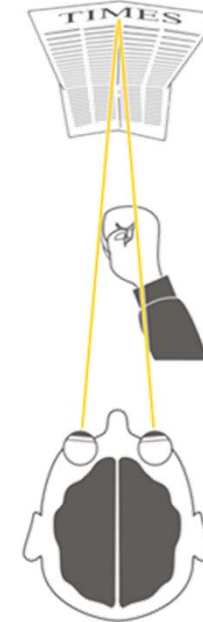
Motion Parallax



Stereopsis

<http://www.more3d.com/3-D/Stereoskopie.html>

- Interocular distance (about 6 cm)
- Disparity of images projected onto the retina
- Processing in the visual cortex of the brain
- Works for distances up to 7 m



Depth Cue	Scope	Classification	Position Estimation
Occlusion	full range	mono-ocular	relative
Disparity	< 10m	bi-ocular	relative
Convergence	< 2m	bi-ocular	absolut
Accomodation	< 2m	mono-ocular	absolut
Image Blur	full range	mono-ocular	relative
Linear Perspective	full range	mono-ocular	absolut
Texture Gradient	full range	mono-ocular	relative
Relative Size	full range	mono-ocular	absolute
Known Size	full range	mono-ocular	absolute
Height in Visual Field	> 30m	mono-ocular	relative
Atmospheric Perspective	> 30m	mono-ocular	relative
Shape from Shading	full range	mono-ocular	relative
Shadows	full range	mono-ocluar	relative
Motion Parallax	> 20m	dynamic	relative
Accretion	full range	dynamic	relative

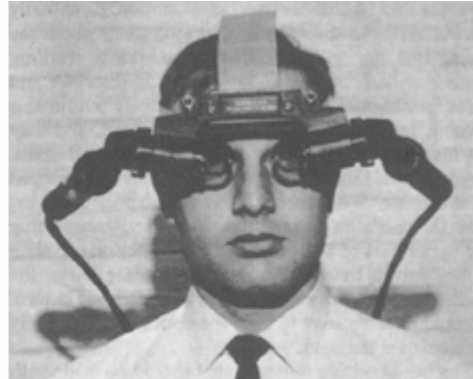
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- **VR Displays and Systems**
- Stereoscopic, Viewer-Centered Projections (VCP)
- VR in Scientific Visualization

The Head Mounted Display



I. Sutherland



Sony



CAE



BOOM



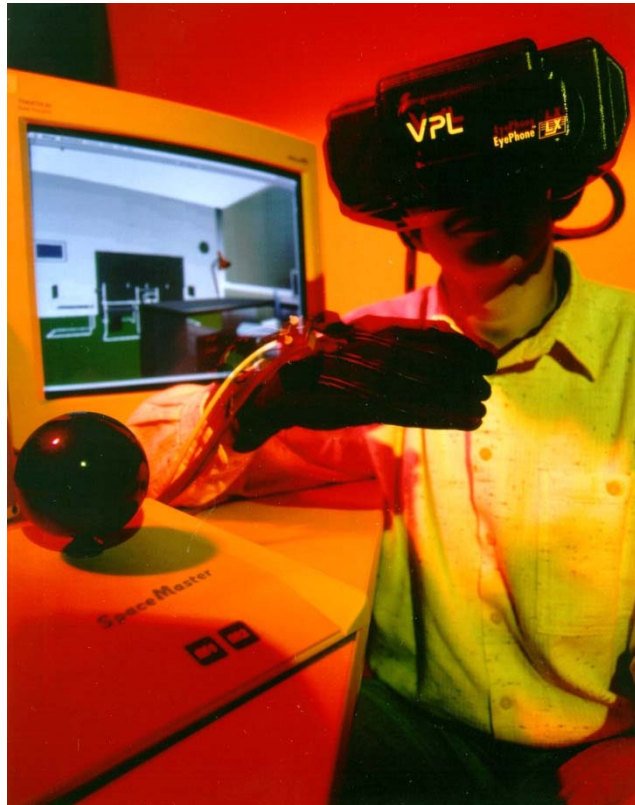
Retina Display,
Microvision

Pictures: diverse Web Sites

Head-Mounted Displays versus Stereo Glasses

Until 1994:

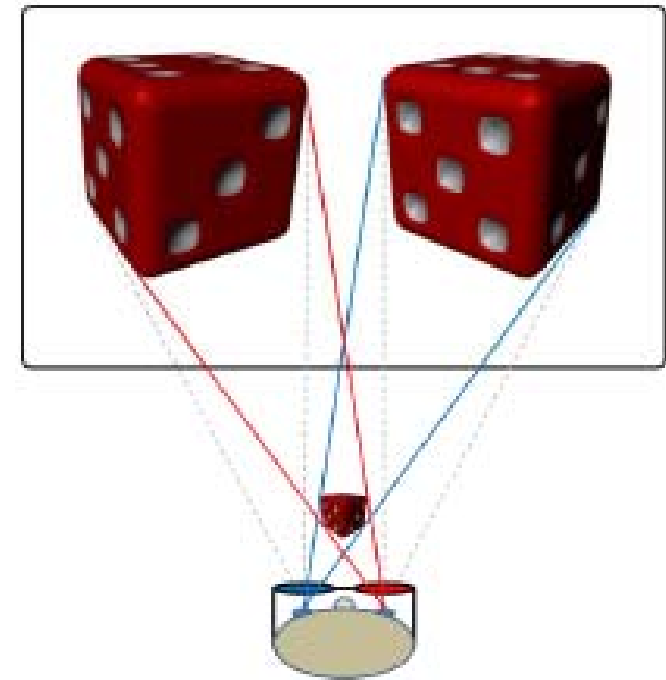
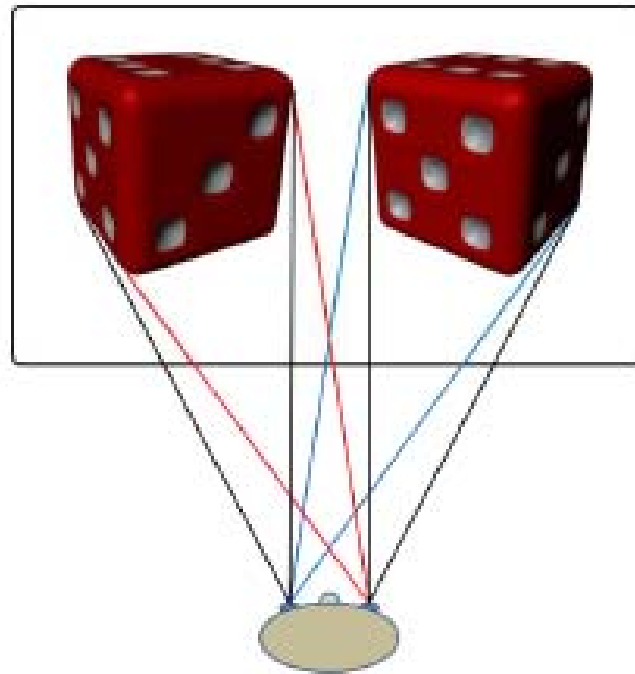
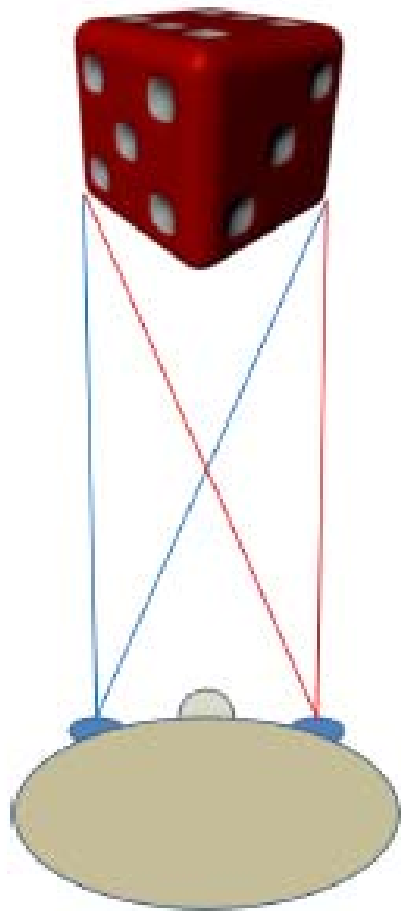
VR = HMD + Instrumented Glove



Stereo Glasses (here: Shutter)

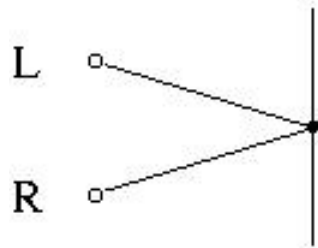


Stereo Parallax in Room-Mounted Displays

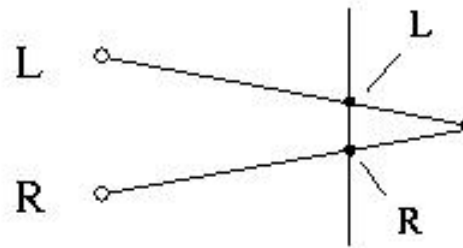


Tom Vaughan,
www.cyberlink.com

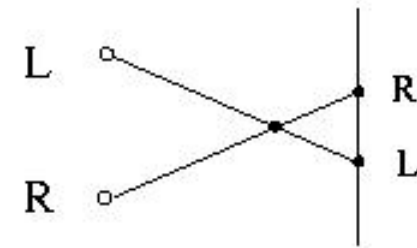
Stereograms



zero parallax



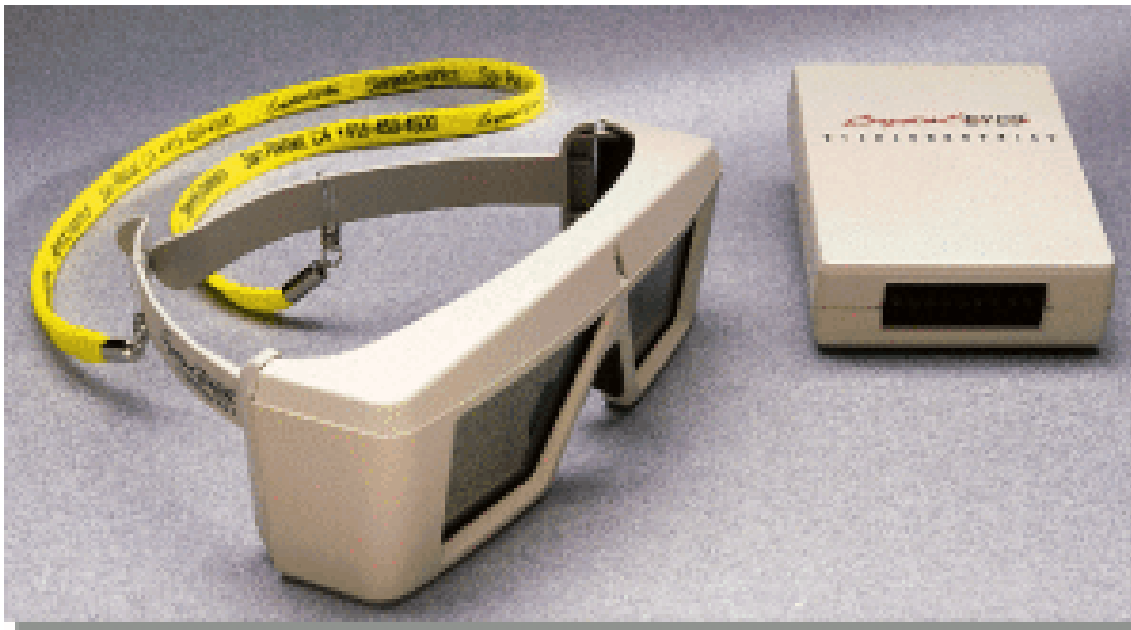
non-crossed
(positive) parallax



crossed
(negative) parallax

Stereo Glasses: Shutter (“Active Stereo”)

- Time Multiplex
- Genlocking of multiple graphics hardware

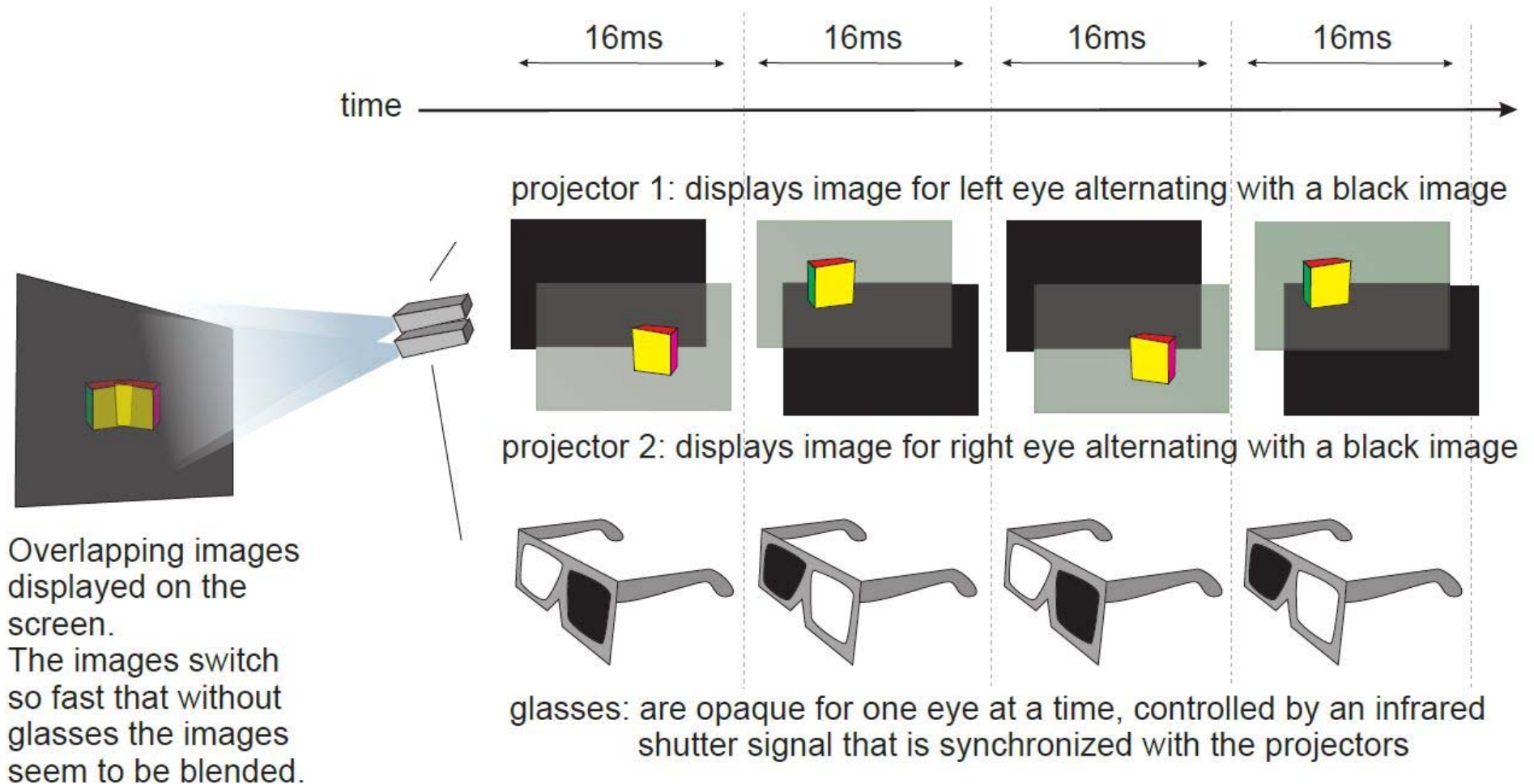


Infrared Stereo Emitter:
Synchronization of glasses and graphics hardware



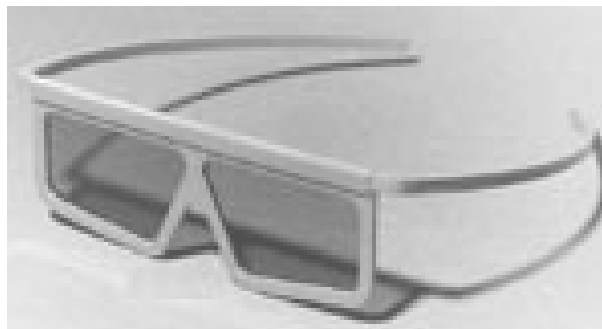
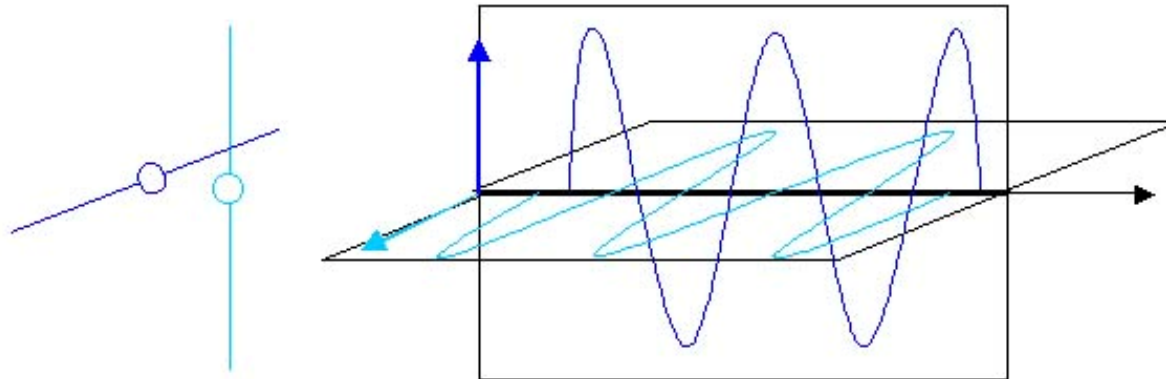
Shutter Glasses with markers
for opto-electronical tracking

Stereo Glasses: Shutter (“Active Stereo”)

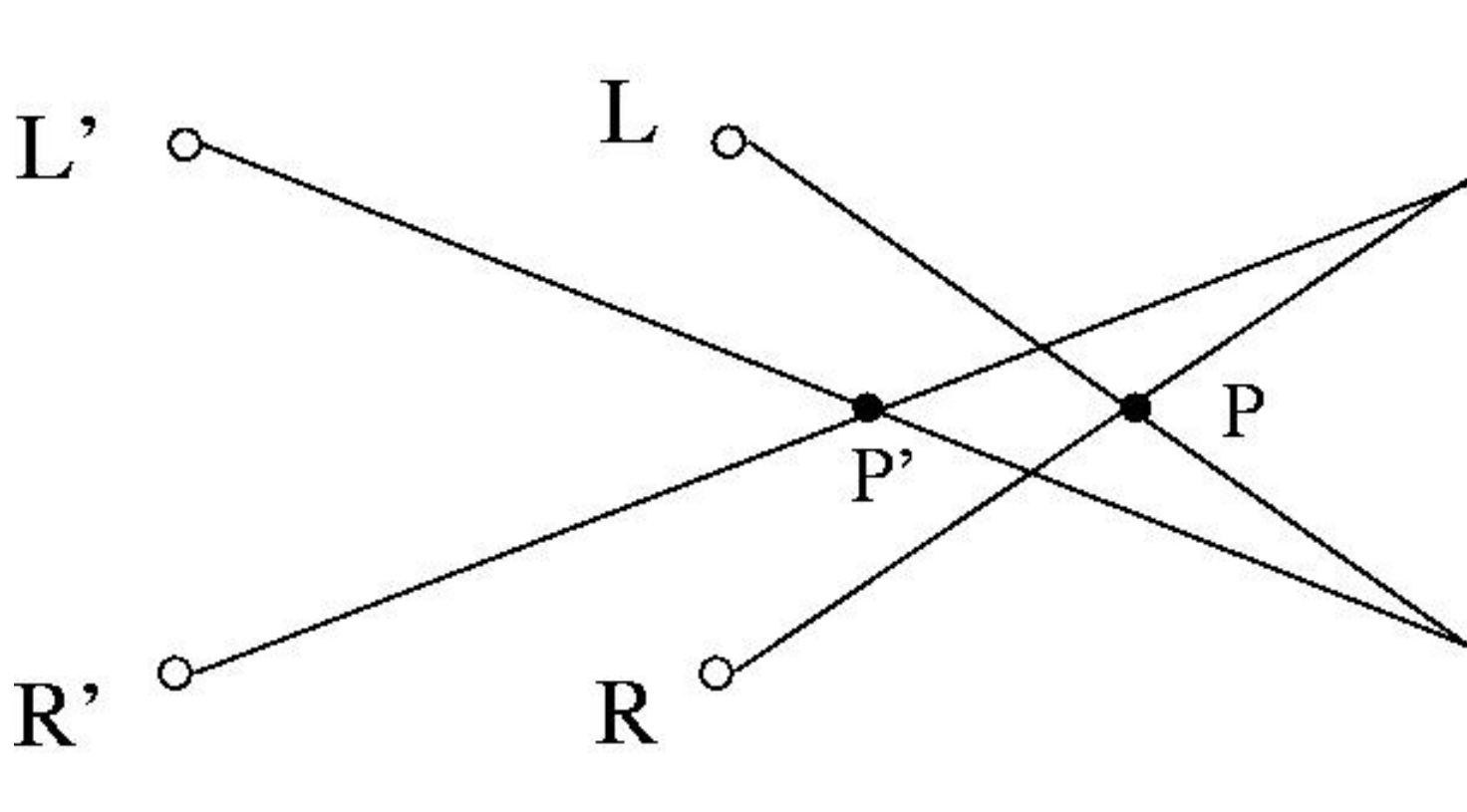


Stereo Glasses: Polarization (“Passive Stereo”)

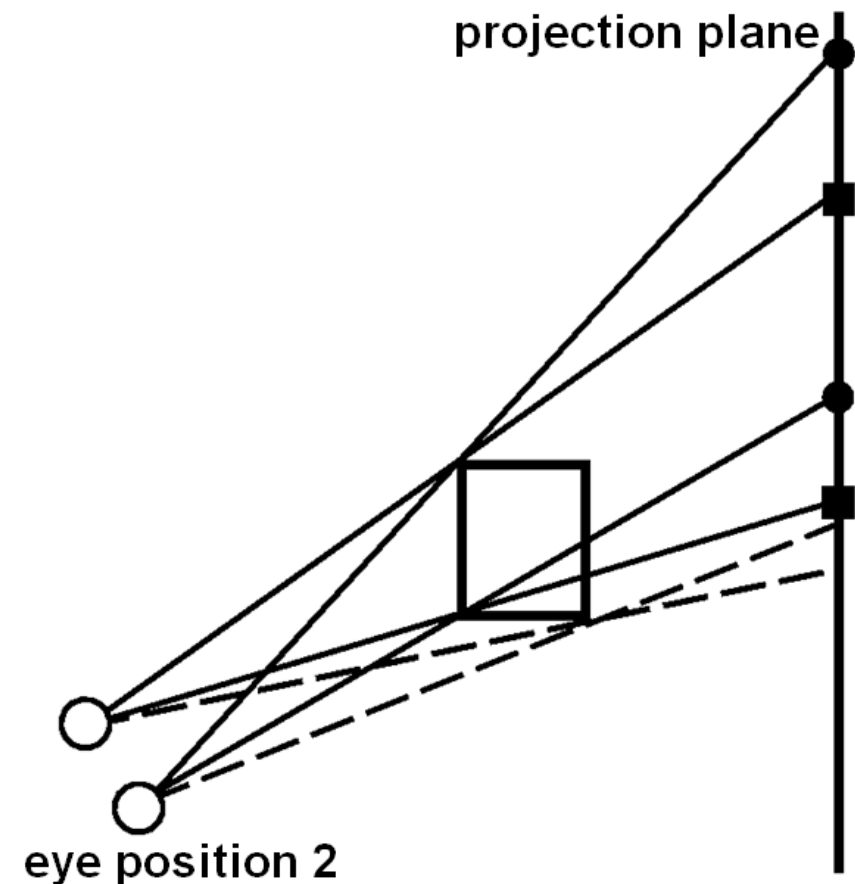
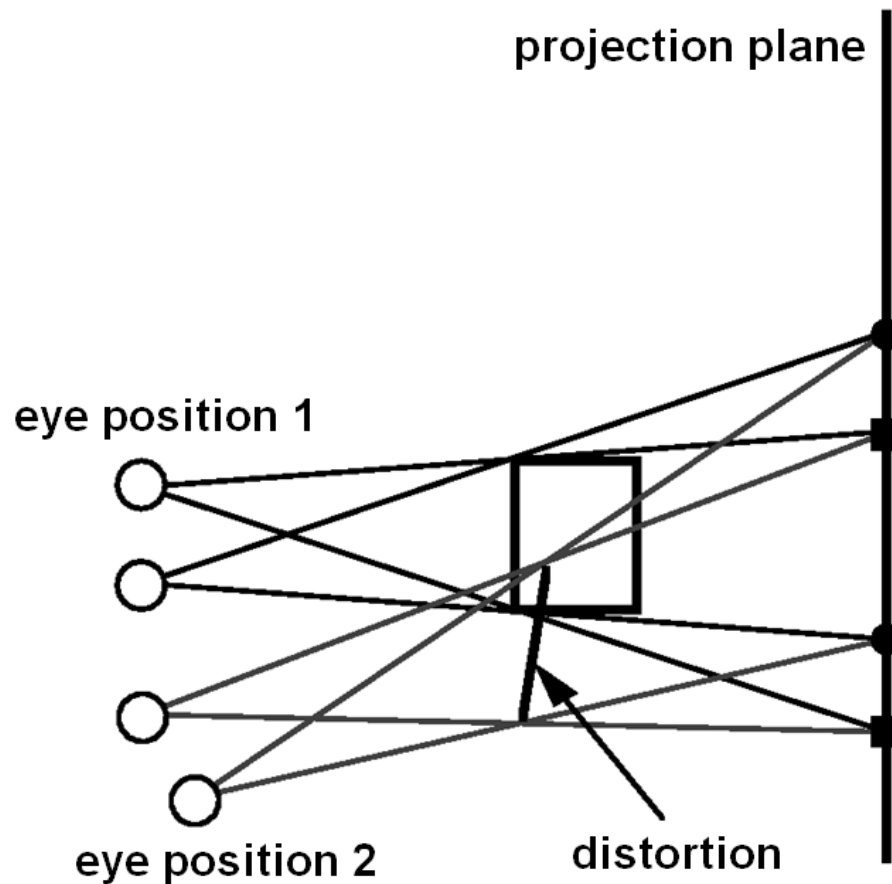
- Linear or circular polarization
- Swap (and Frame) locking of multiple graphics hardware
- screen material may not destroy polarization (hot spot)



Distortions in Static Stereograms



Adaptation of projection to the viewpoint



Electromagnetic Tracking - Polhemus



Electromagnetic Tracking in Military



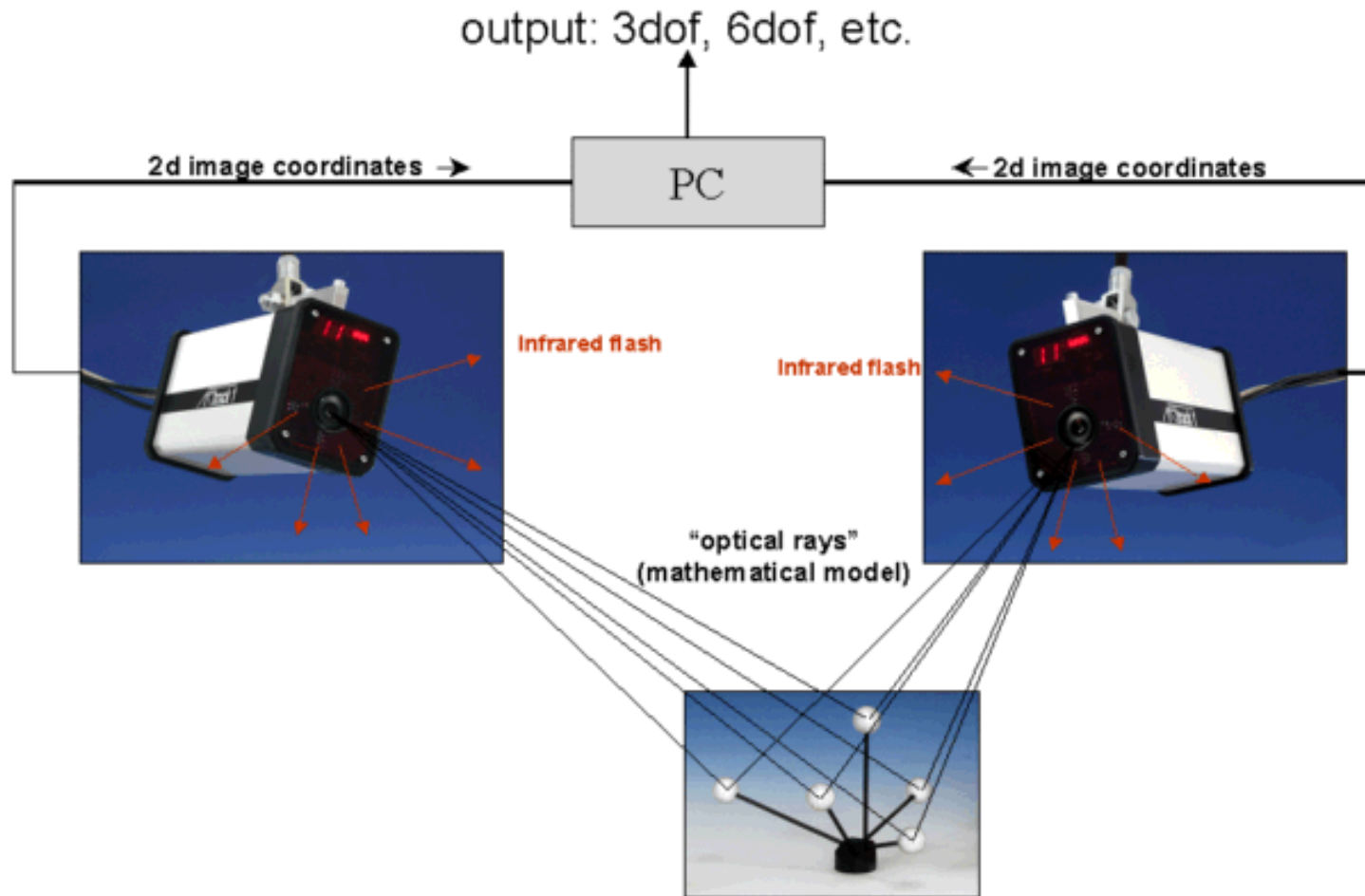
JSF Simulator Courtesy of Boeing

Electromagnetic Tracking – Pros & Cons

- + Position & orientation
- + No occlusion
- sensitive to ferromagnetic materials in the environment
- Accuracy decreases with growing distance between sender and receiver
- Rather large sensors (1-2 cm)

Optoelectronic Tracking – A.R.T.

Picture: A.R.T. GmbH



Optoelectronic Tracking – Pros & Cons

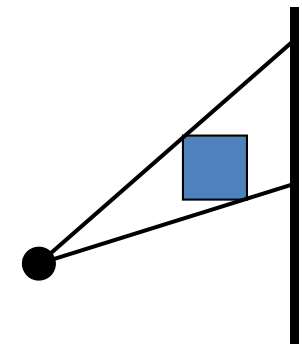
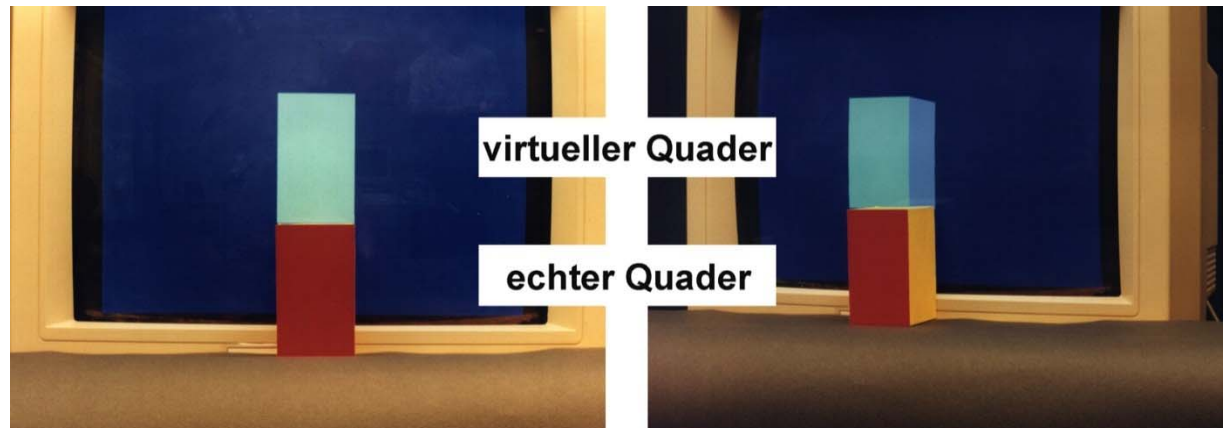
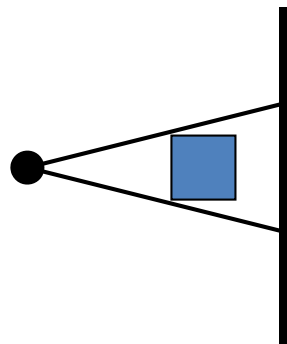
- + Accuracy, latency sample rate (of today's systems)
- + Passive markers: No cabling, nearly non-intrusive
- Occlusion
- No orientation (combine 3 non-collinear markers)
- Calibration process (rather comfortable in today's systems)

The Principle of Viewer Centered Projection (VCP)

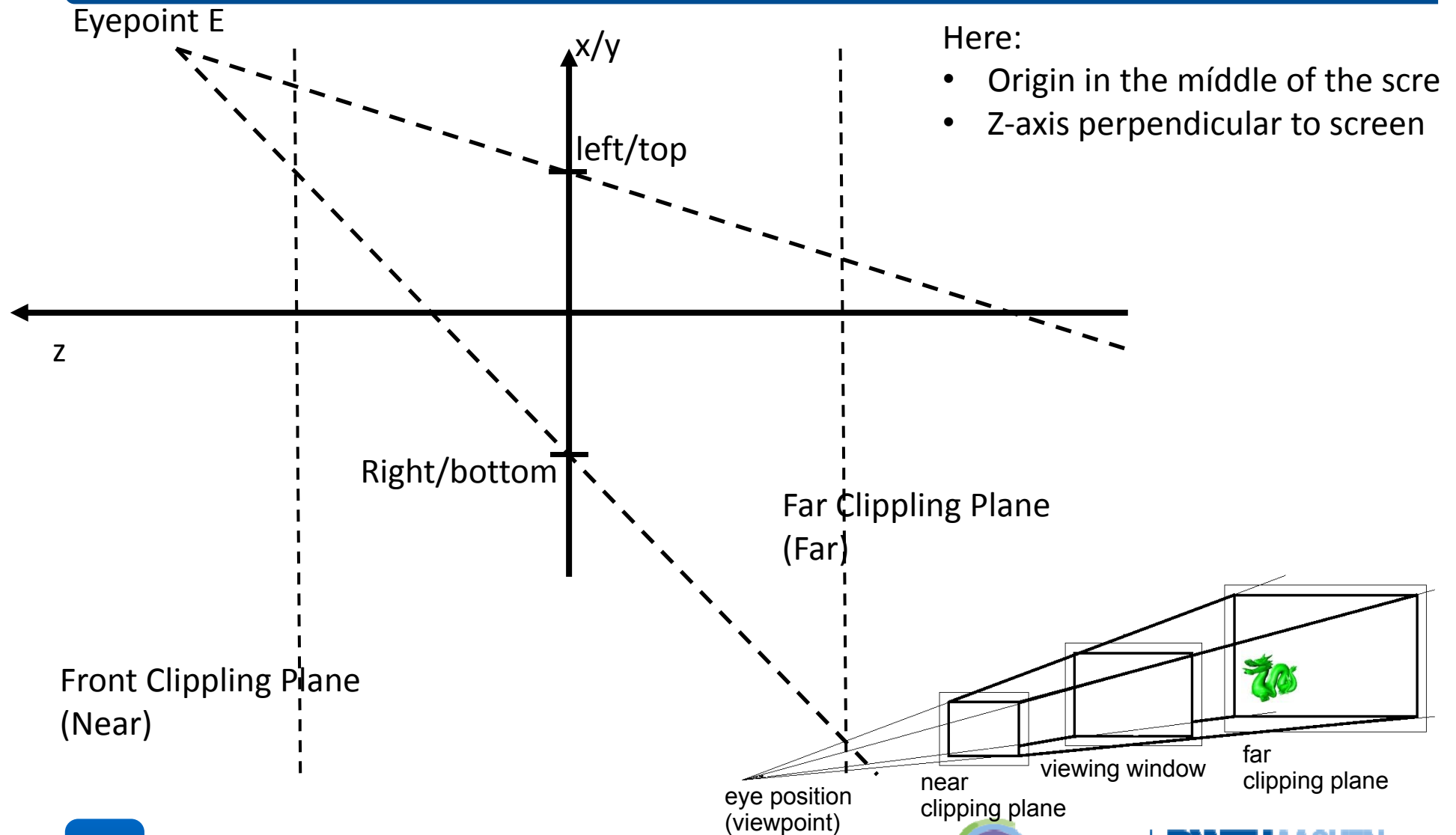
stereo parallax



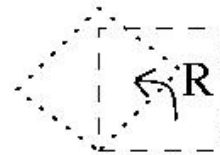
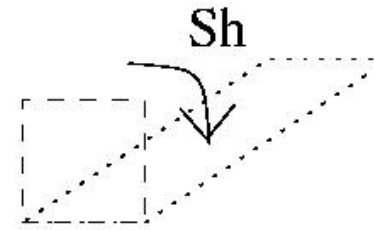
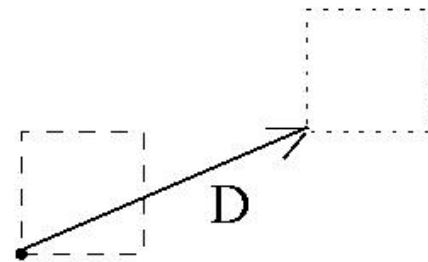
motion parallax



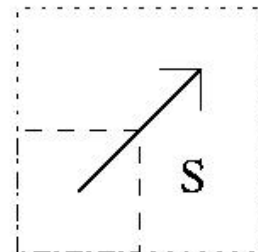
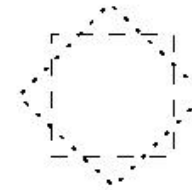
Diagonal Projection



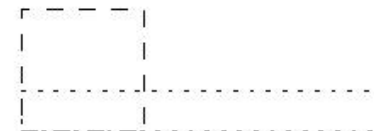
Basic Operations



or

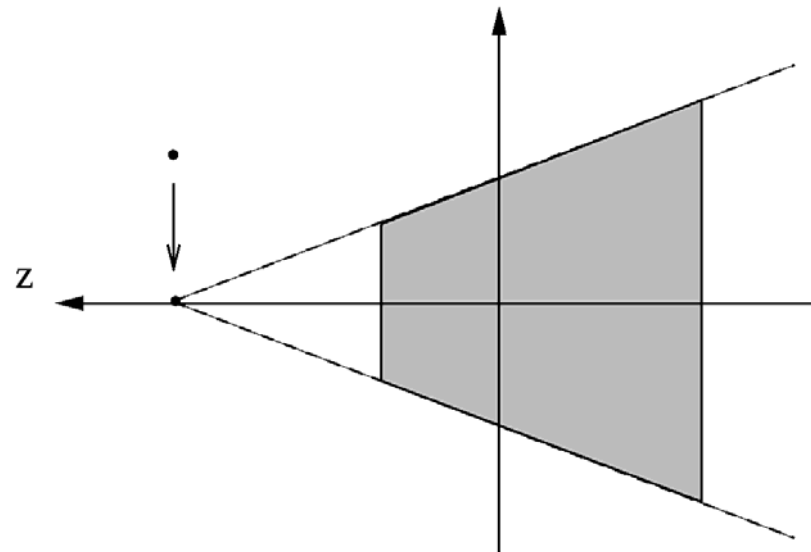


or



Shearing of the View Volume

$$P_1 = SH_{xy}\left(\frac{-E_x}{E_z}, \frac{-E_y}{E_z}\right) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \frac{-E_x}{E_z} & \frac{-E_y}{E_z} & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$



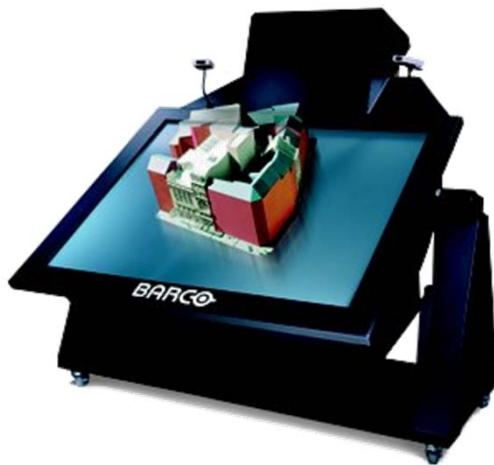
The Projection Matrix

Parameters:

- Position of the view window: left, right, top, bottom
- Near and far clipping plane: near, far
- Eye position E

$$\mathbf{P} = \begin{pmatrix} \frac{2e_z}{r-l} & 0 & 0 & 0 \\ 0 & \frac{2e_z}{o-u} & 0 & 0 \\ \frac{-2(e_x - \frac{r+l}{2})}{r-l} & \frac{-2(e_y - \frac{o+u}{2})}{o-u} & \frac{2e_z - f - n}{f-n} & -1 \\ -\frac{r+l}{r-l}e_z & -\frac{o+u}{o-u}e_z & \frac{-e_z(2e_z - f - n) + 2(f - e_z)(n - e_y)}{f-n} & e_z \end{pmatrix}$$

Viewer Centric Projection (VCP) on a Workbench



Tracked Virtual Table

- tiltable BARON table
- optically tracked
- real-time recalibration
- extended working volume

Effect of Motion Parallax

Courtesy of Bill Sherman



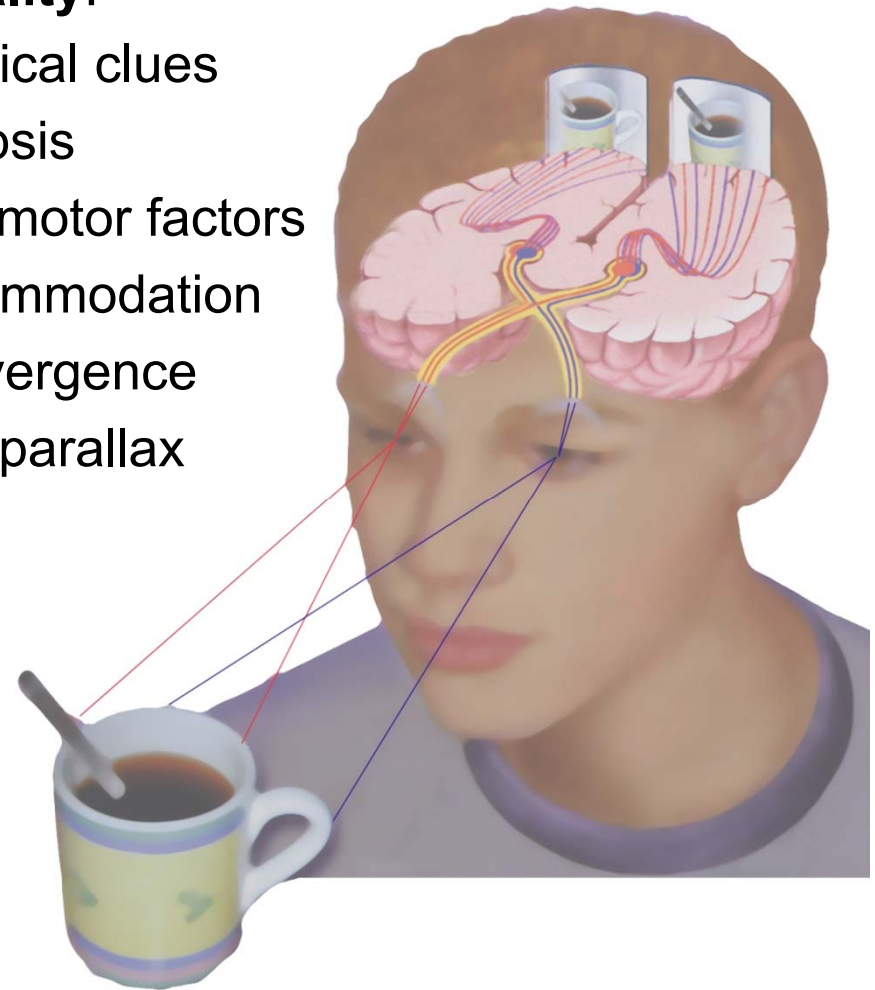
3D Vision: Physiological & Psychological Cues

Traditional **CG**:

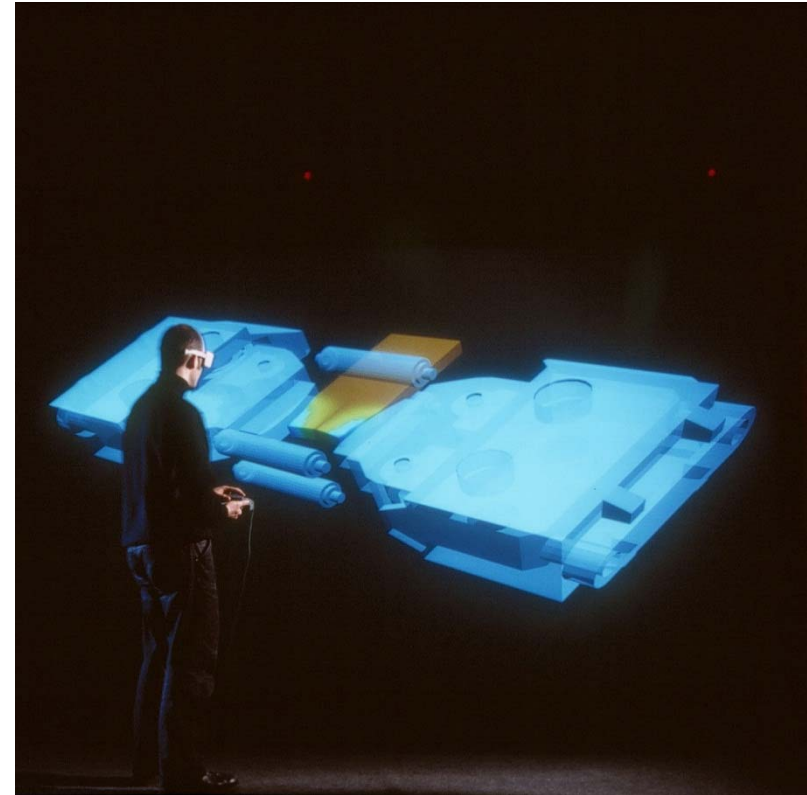
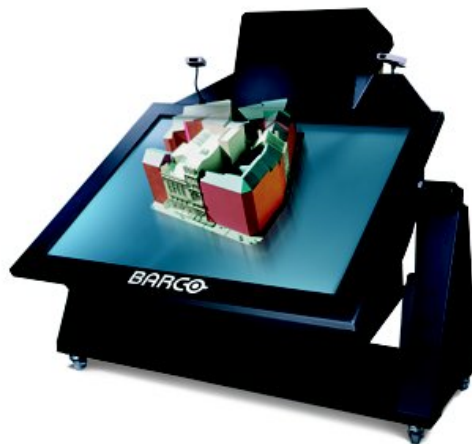
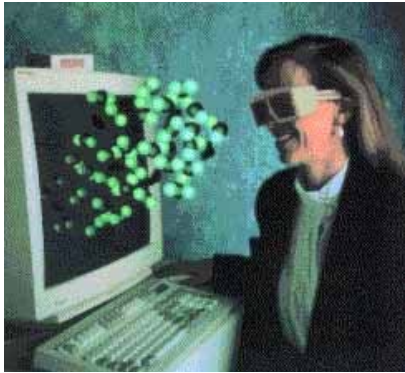
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Virtual Reality:

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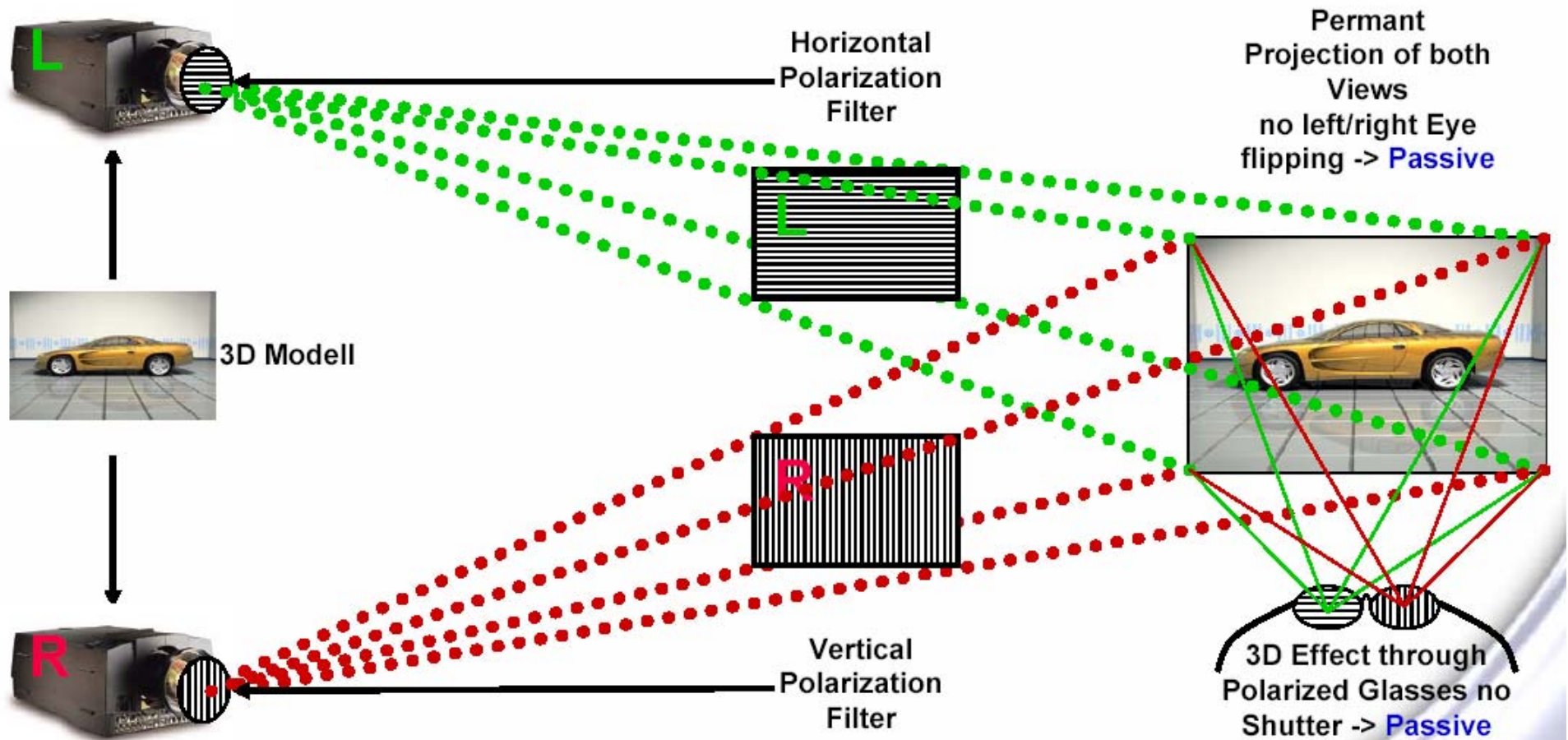


PowerWall

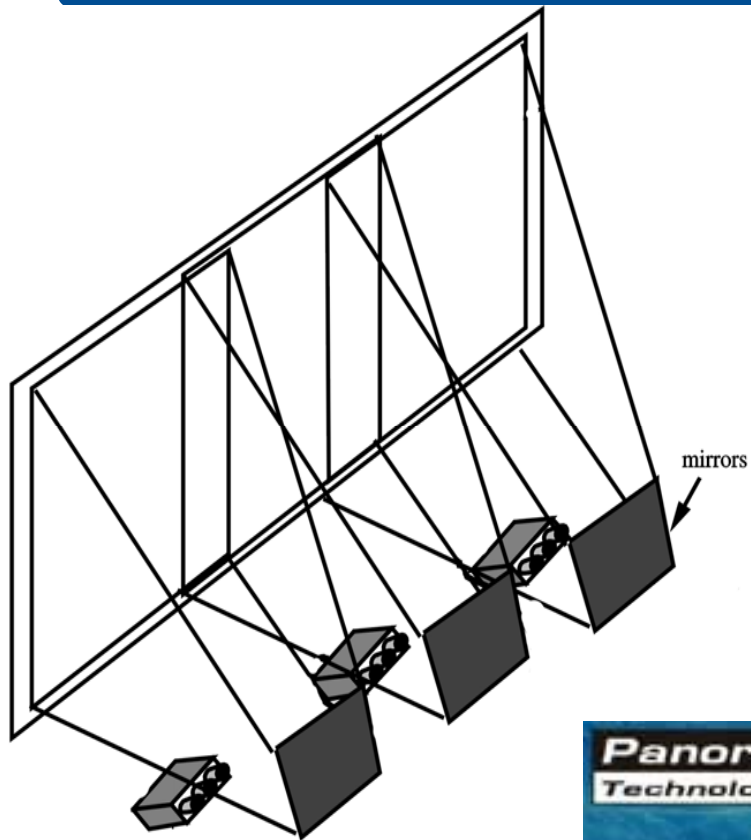


Analysis of forming processes on a PowerWall
(IBF and RZ, 2000)

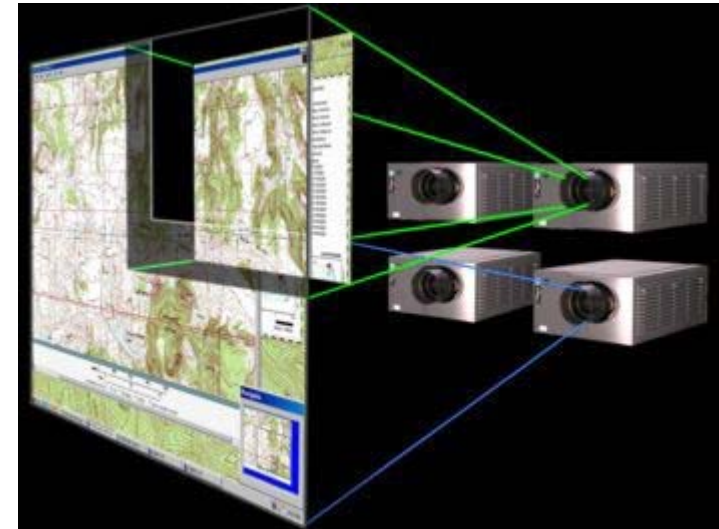
Stereo Glasses: Polarization (cont.)



Multi Projector PowerWall



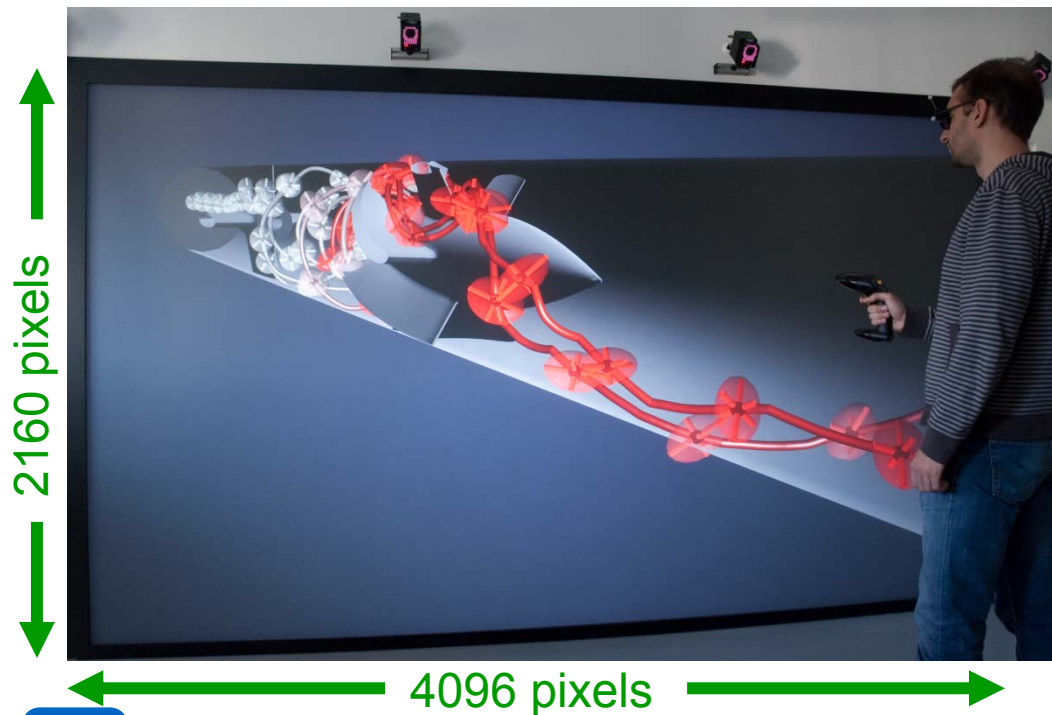
Picture: Burdea et al.



Pictures: Panoram Technologies, Indeed Visual Concepts



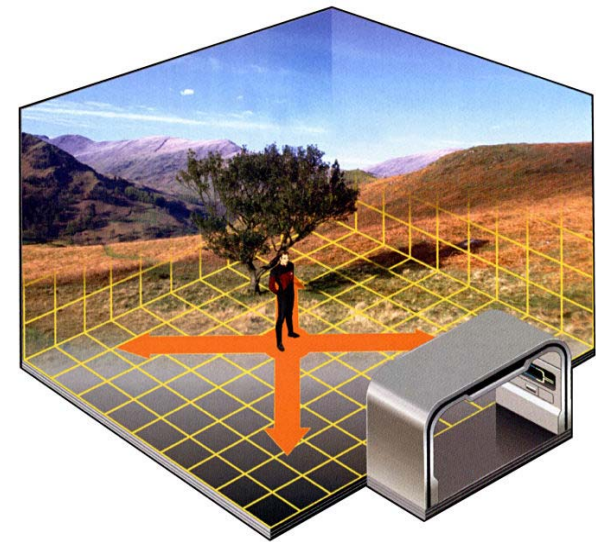
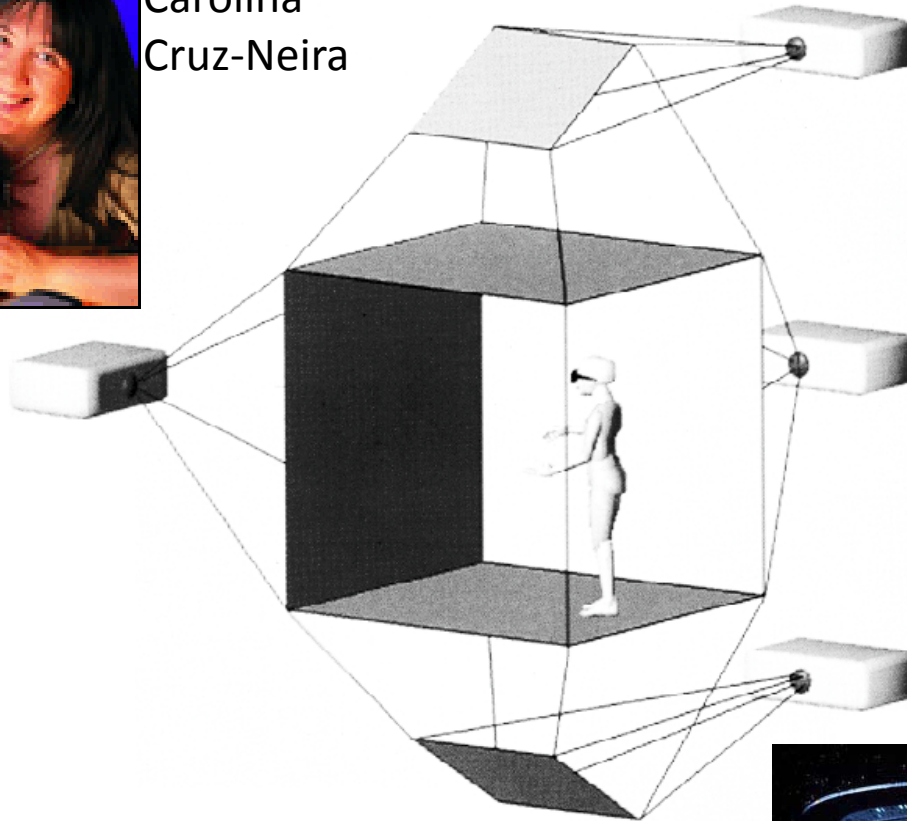
High Resolution PowerWall @ AICES Graduate School



The CAVE, 1993

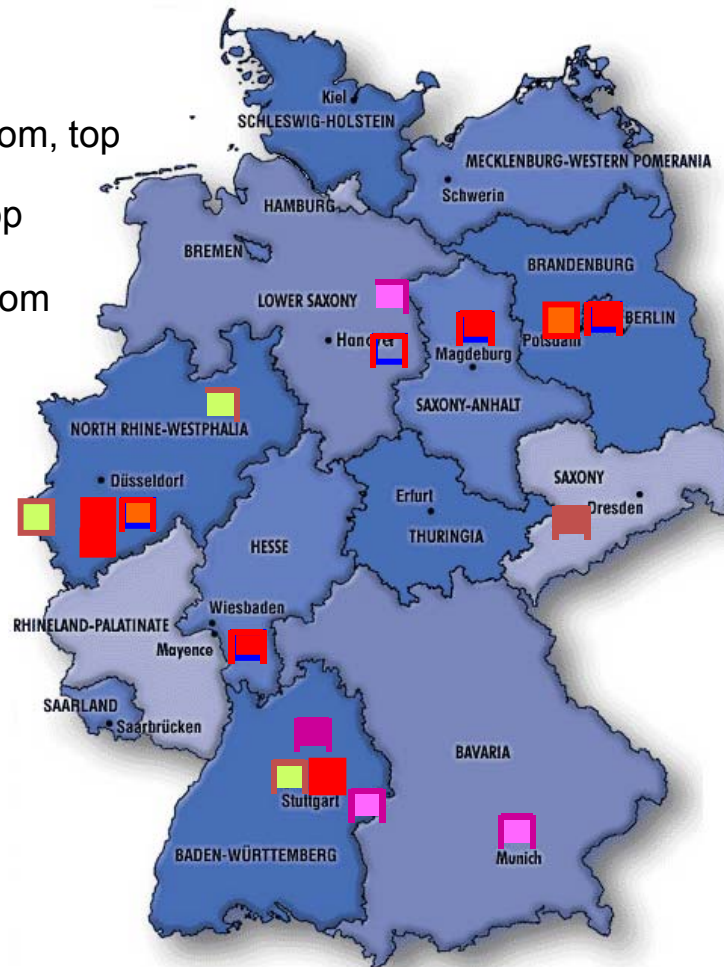


Carolina
Cruz-Neira



CAVE Installations in Germany in 2004

- • Front, back, left, right, bottom, top
- • Front, left, right, bottom, top
- • Front, back, left, right, bottom
- • Front, left, right, bottom
- • Front, left, bottom
- • Front, left, right



(2004, maybe incomplete)

Research Institutes

- Stuttgart, Fraunhofer IAO/IPA (6)
- Bonn caesar (7)
- Darmstadt, Fraunhofer IGD (5)
- Magdeburg, Fraunhofer IFF (5)
- Berlin Fraunhofer IPK (5)
- Berlin Fraunhofer First (5)
- St. Augustin Fraunhofer IMK (4)
- Braunschweig DLR (3)

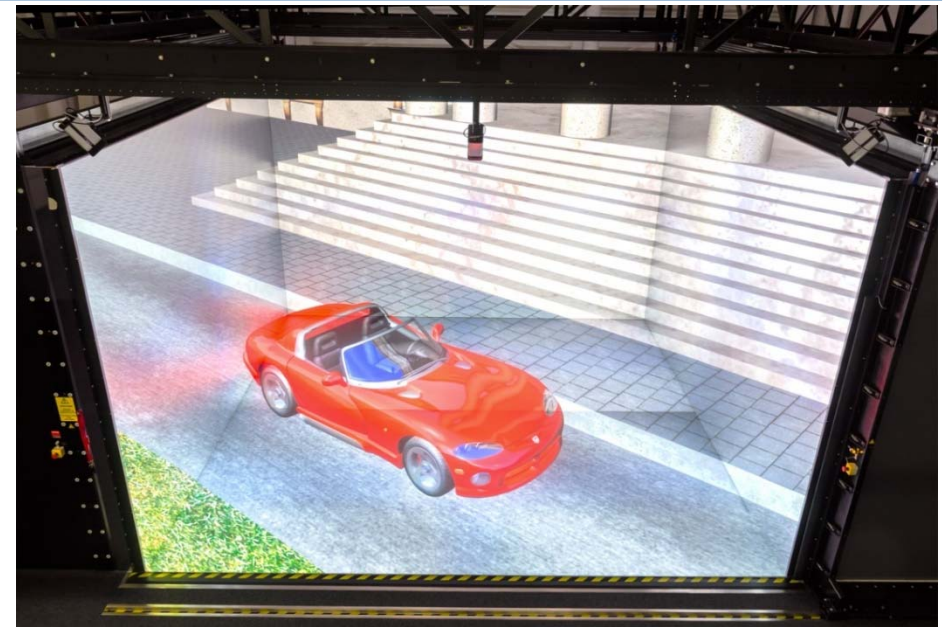
Industry

- München, BMW (4)
- Sindelfingen, DaimlerChrysler (5)
- Ulm, DaimlerChrysler (4)
- Wolfsburg, VW (3)

University

- Aachen RWTH, RZ (5)
- Bielefeld Univ. AG KI (3)
- Chemnitz, TU (5)
- Stuttgart Univ., HLRZ (4)

The aixCAVE @ RWTH Aachen

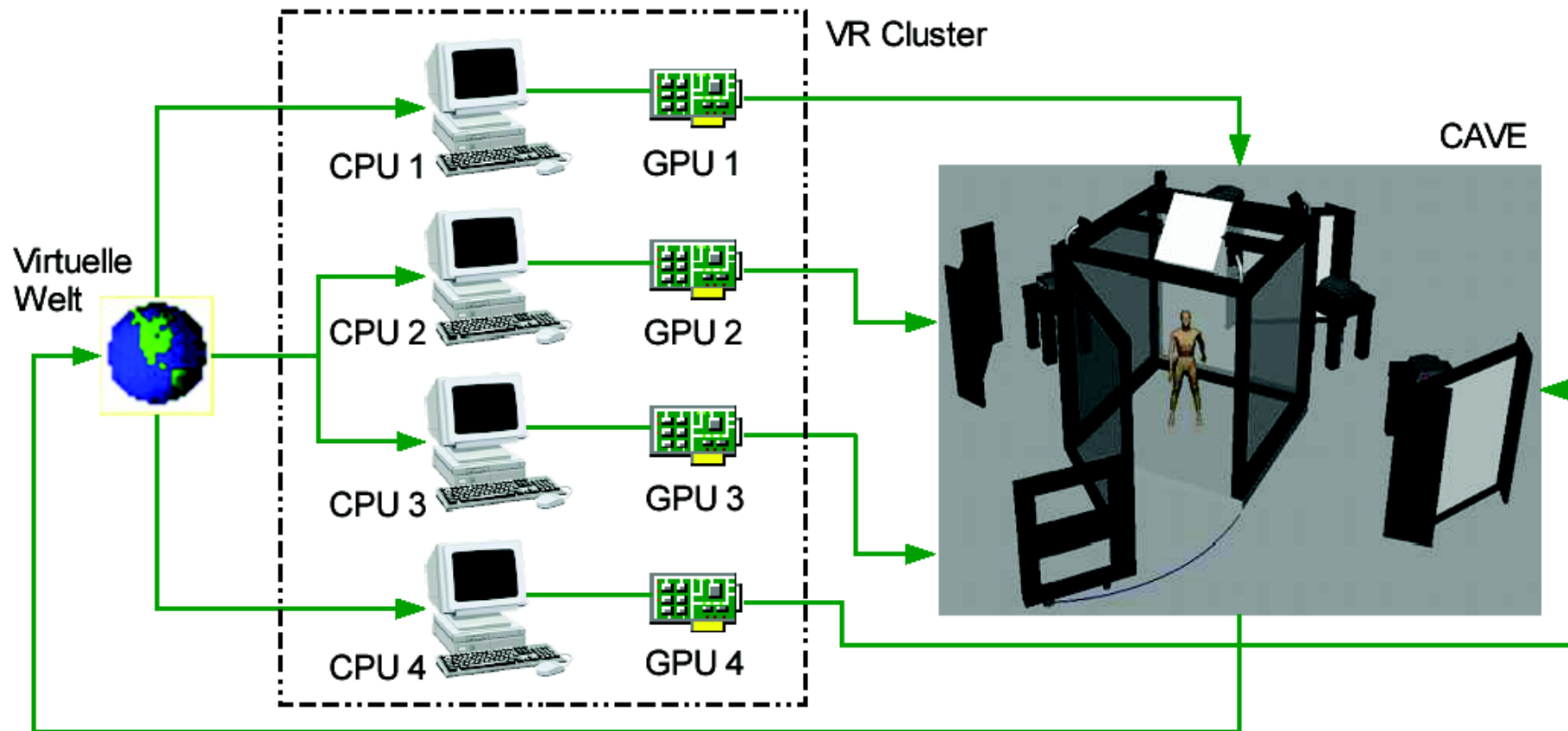


Same visual perception in real & virtual world!

➡ Realize stereo **AND** motion parallax

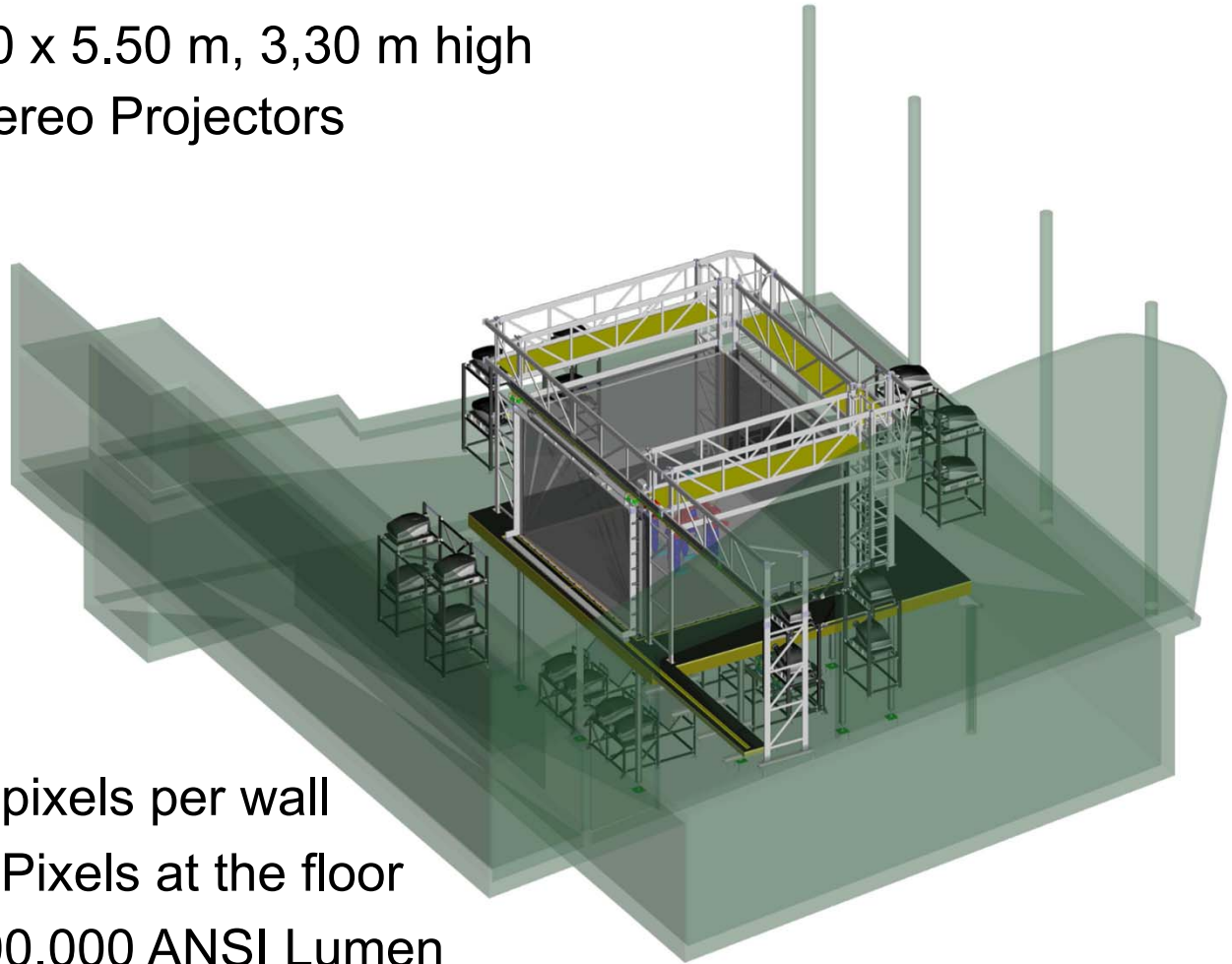


PC Clusters for Immersive Displays



The aixCAVE Specs

- Footprint approx. 5.50 x 5.50 m, 3,30 m high
- 24 WUXGA Active Stereo Projectors



- Approx. 3200 x 2000 pixels per wall
- Approx. 3600 x 3600 Pixels at the floor
- Brightness: Nearly 300.000 ANSI Lumen

VCP in the aixCAVE

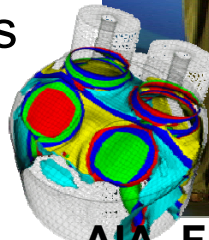


Topics

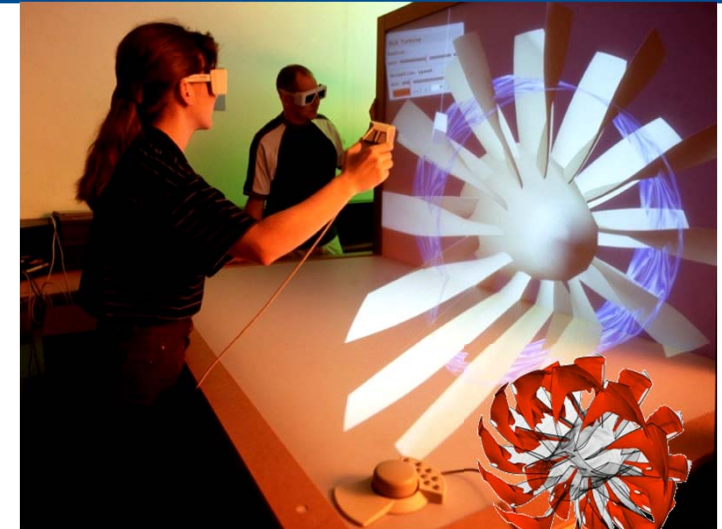
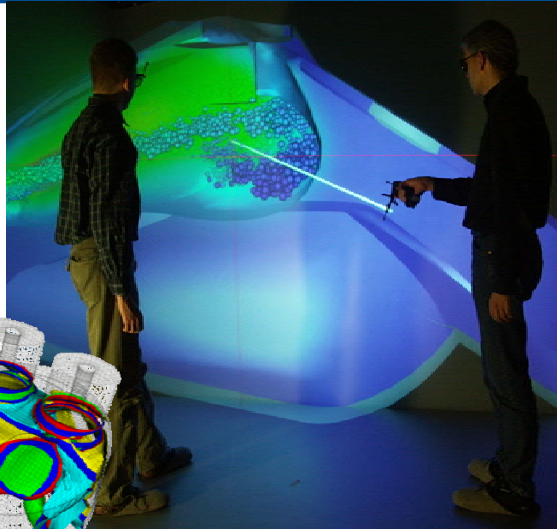
- What is Virtual Reality?
- VR Displays and Systems
- Stereoscopic, Viewer-Centered Projections
- VR in Scientific Visualization

VR Applications in CES @ RWTH

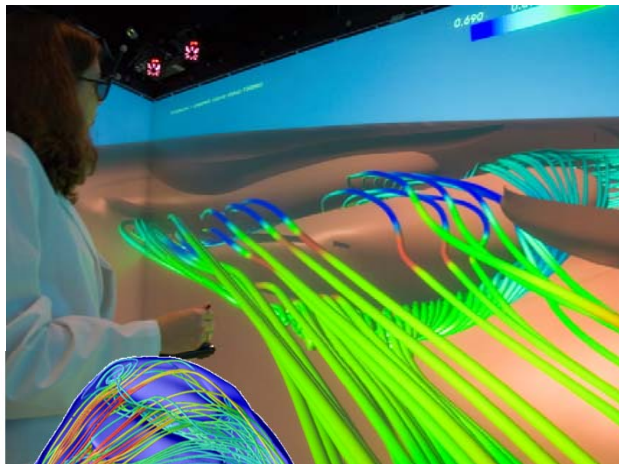
- Motors & Turbines
- Twin Extruders
- Nasal Airflow
- Blood Flow
- Crash Simulations
- Material Science
- Pig housing



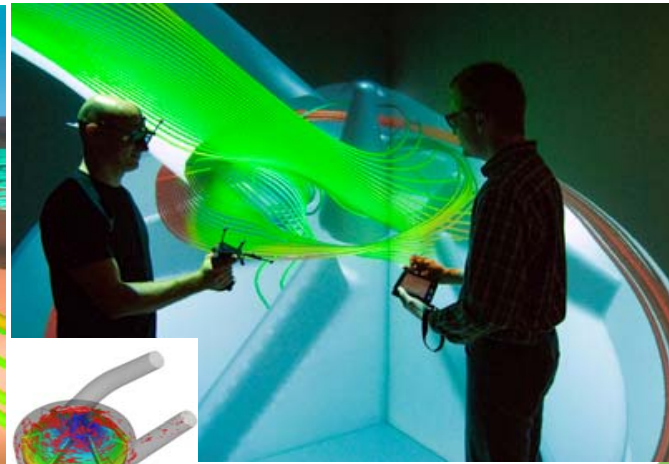
AIA, FEV GmbH, VR Group



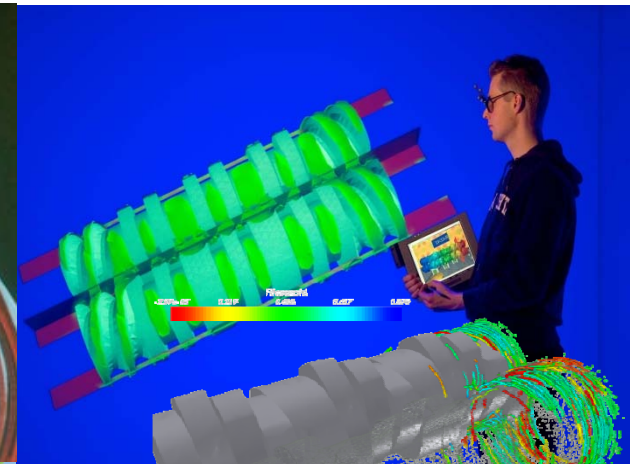
DLR, IST, VR Group



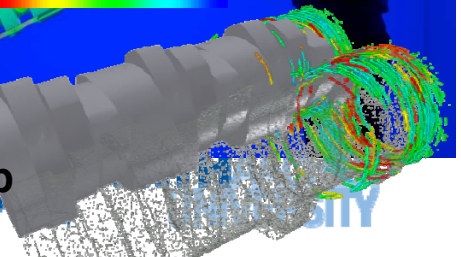
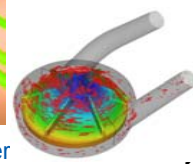
AIA, VR Group



VR Group

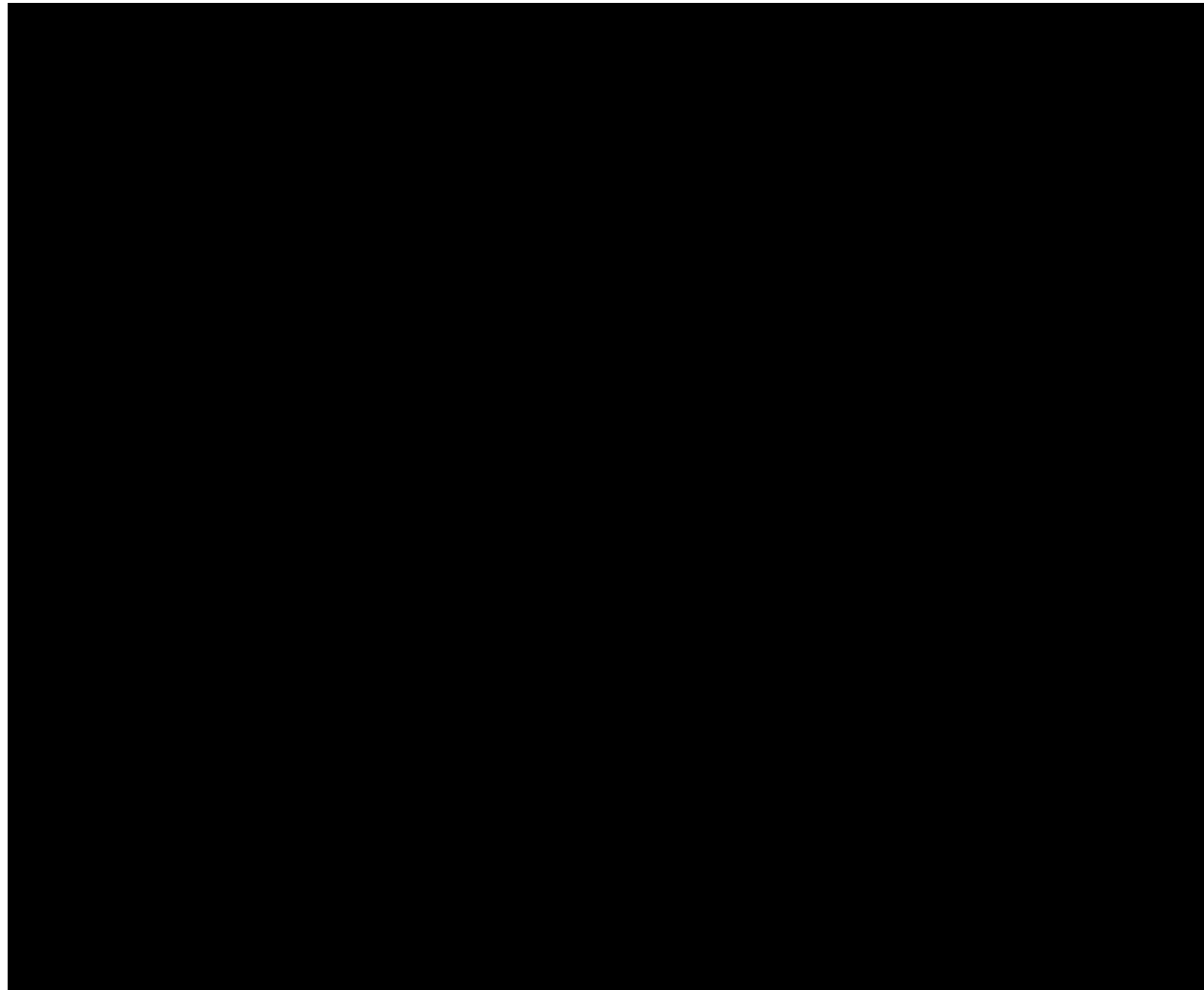


IKV, VR Group



Video: Counter Propfan

L. Jerabkova



Motivation



JUQUEEN IBM Blue Gene/Q System, JSC,
Forschungszentrum Jülich GmbH

Increasing Computer Power



Complex Simulations
(3D, fine grids, unsteady)



Explorative (instead of confirmative)
analysis in **3-D space**

- Trial & Error process
- **Interactivity!**

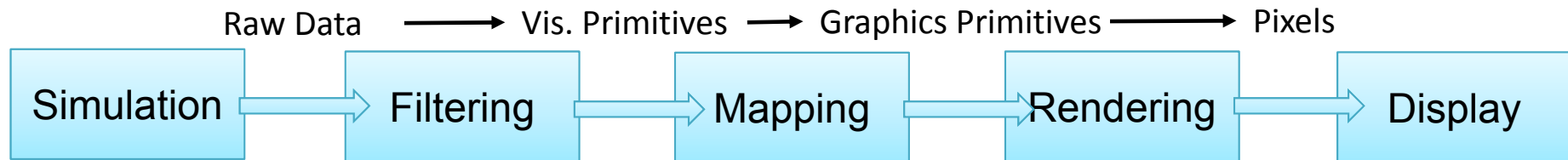


SMP Cluster in Aachen

Challenges

- Performance: Interactivity versus large datasets
- HCI: How to create and interact with complex vis objects in 3D?
How to navigate in space and time?

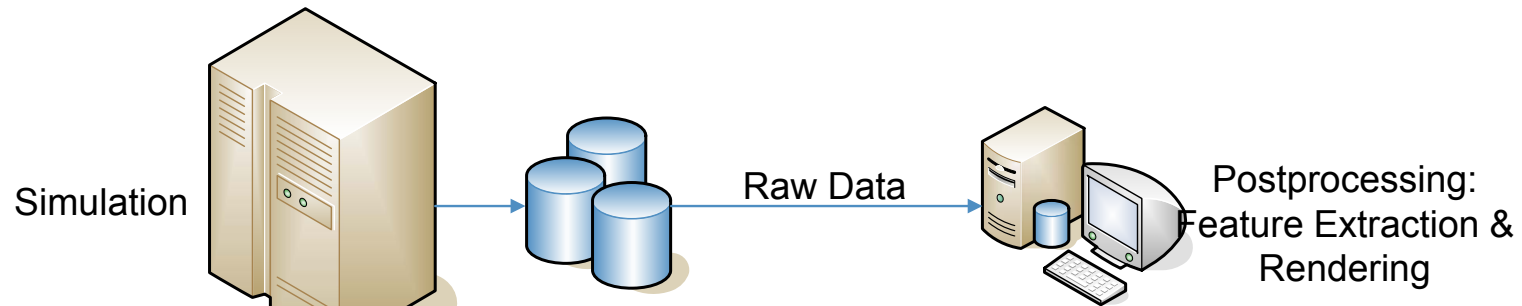
Levels of Interactivity



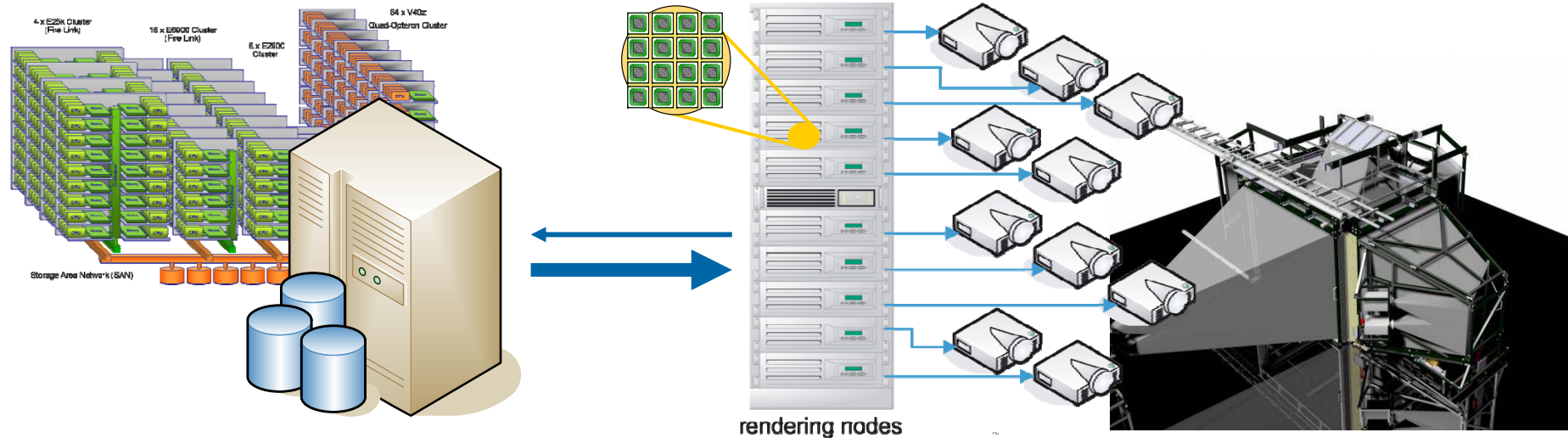
- **What is interactive?**

- Nothing
 - Image, Animation (Movie)
- Rendering only
 - Navigation, selection & animation of pre-computed vis. primitives
- Filtering, Mapping, Rendering
 - Interactive Visualization, Interactive Post Processing, Explorative Analysis
- Simulation, Filtering, Mapping, Rendering
 - Interactive Simulation, Computational Steering, Interactive Supercomputing, Human-In-the-Loop

Architecture for VR-based Scientific Visualization



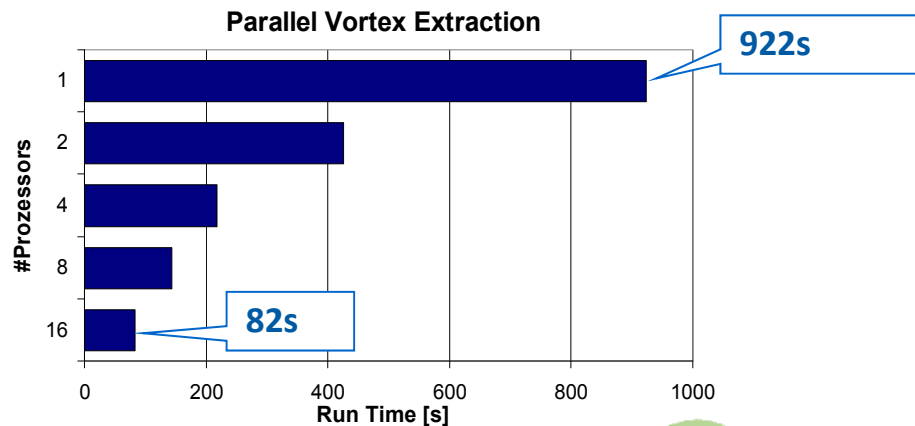
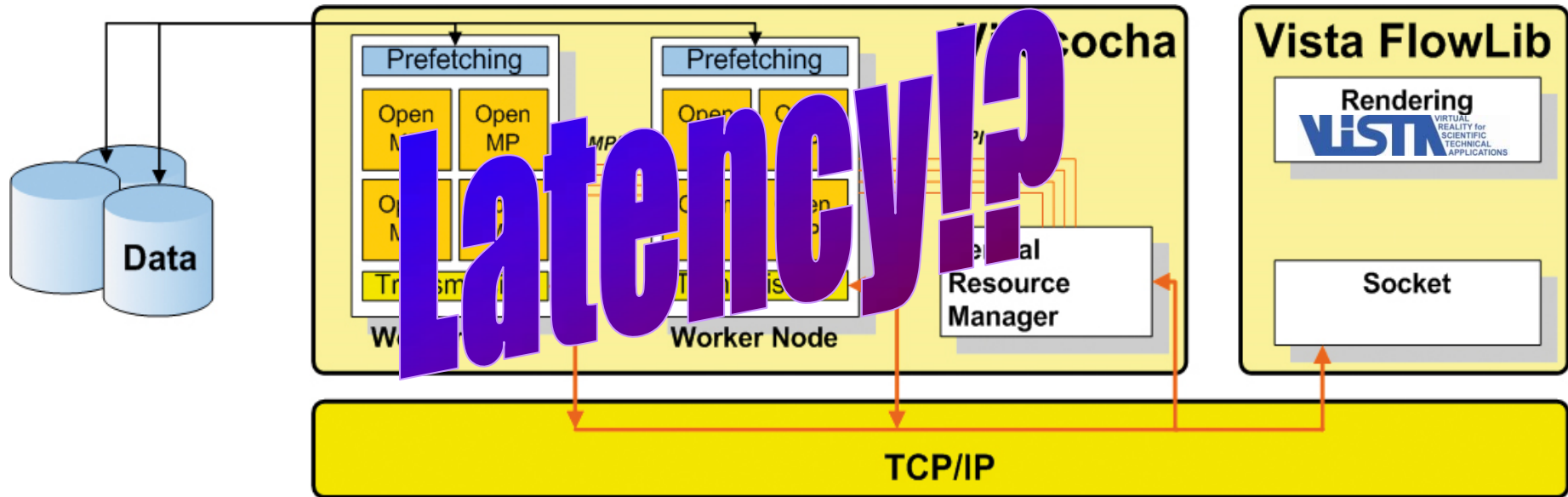
Dilemma: Interactivity versus large datasets



Parallel Framework

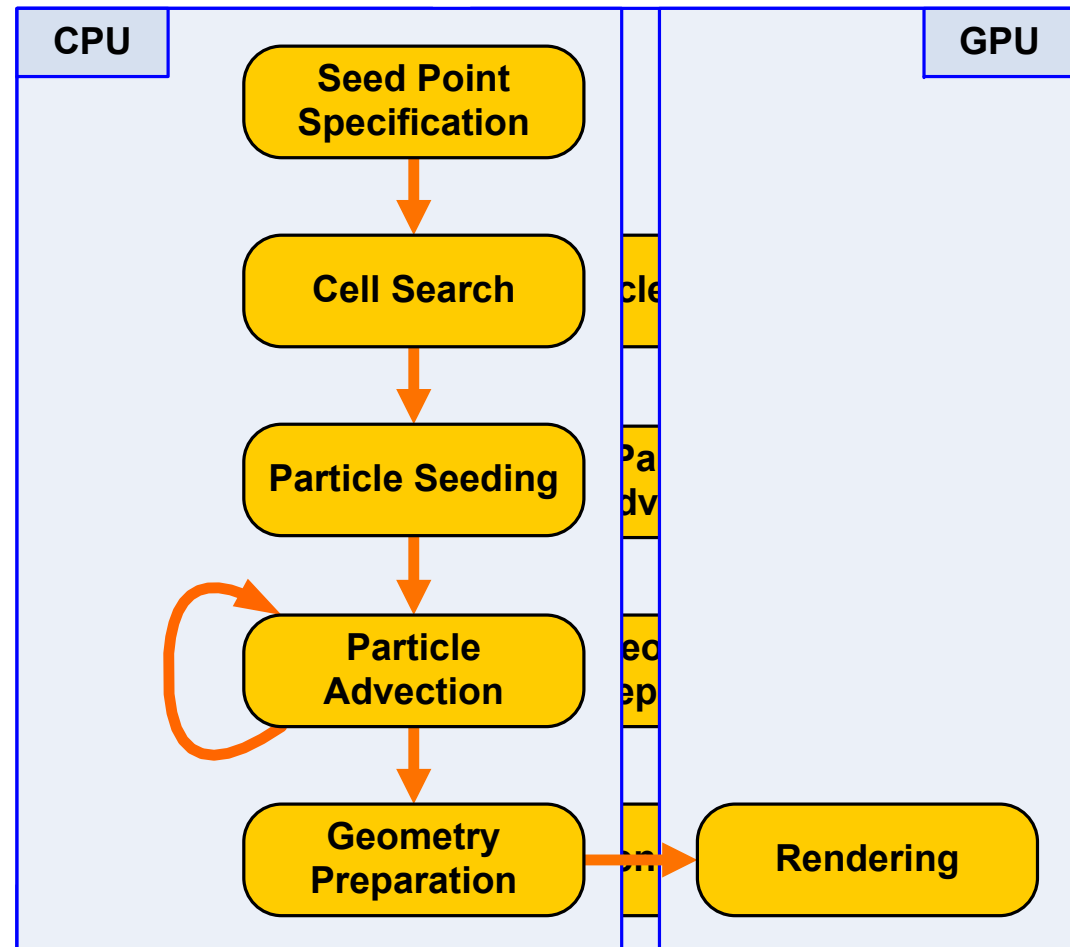
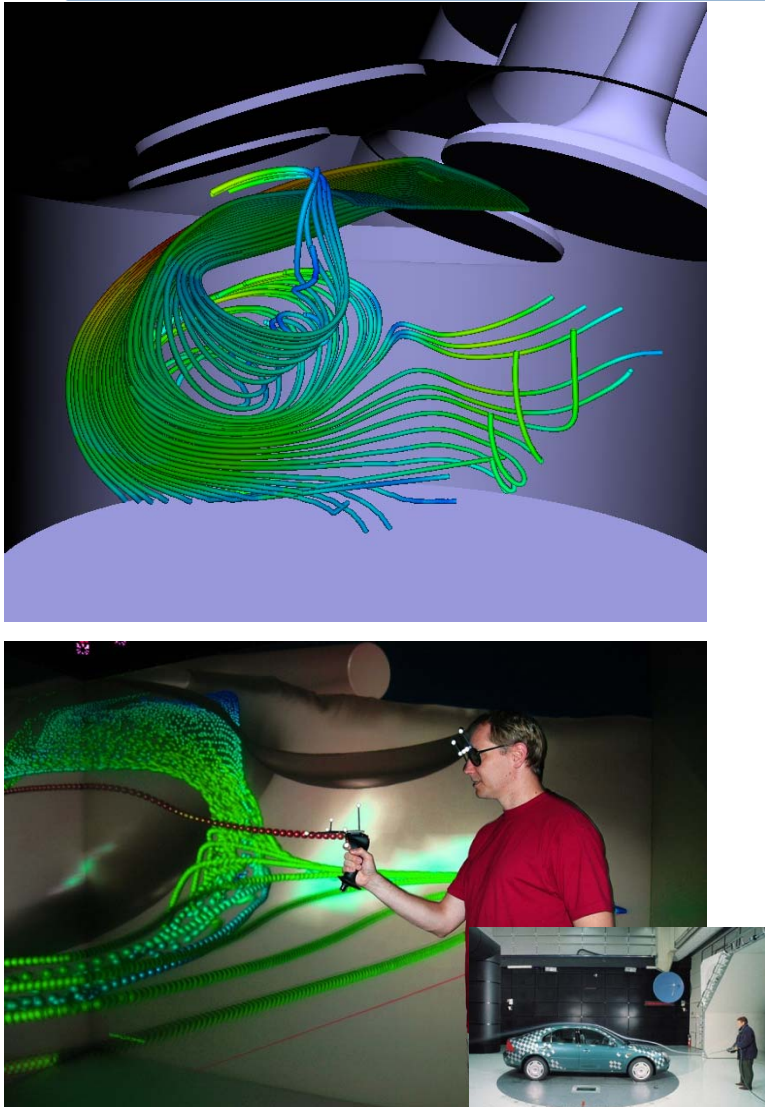
A. Gerndt, M. Wolter, B. Hentschel, I. Assenmacher, I. Tedjo, S. Pick, A. Kelle-Emden

[IMACS 2000, SC 2004, EGVE 2003, EGPGV 2006, SC 2006, EGPGV 2007, ParCo 2007, SEARIS 2008, CGF 28(6)]



Interactive Particle Tracing on the GPU

M. Schirski



“The Virtual Windtunnel Revisited”

Marc Schirski et al.

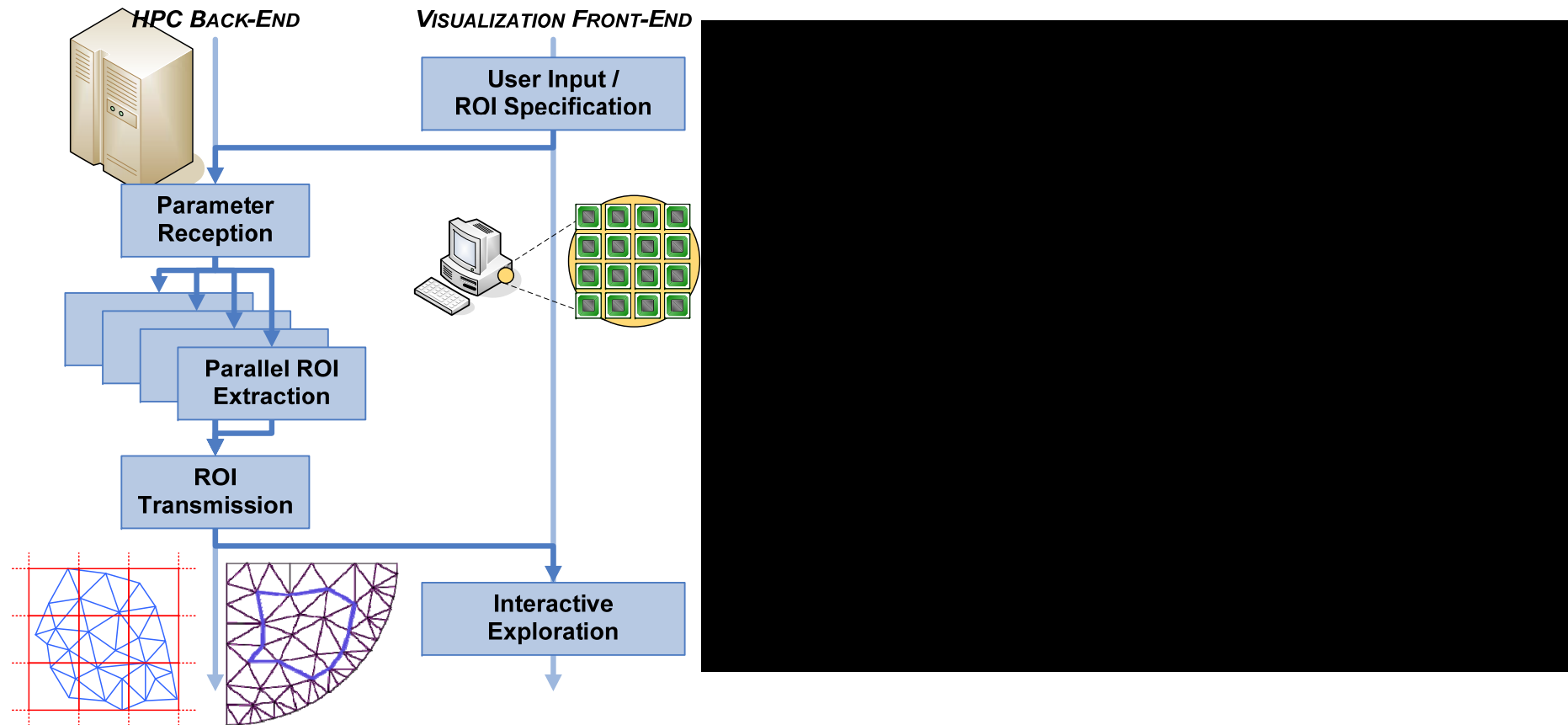


Large Data!?

- GPU-based Real-Time Particle Tracing
- Works for structured as well as unstructured data sets and for time-varying datasets
- Advanced Billboard Rendering (Virtual Tubelets)

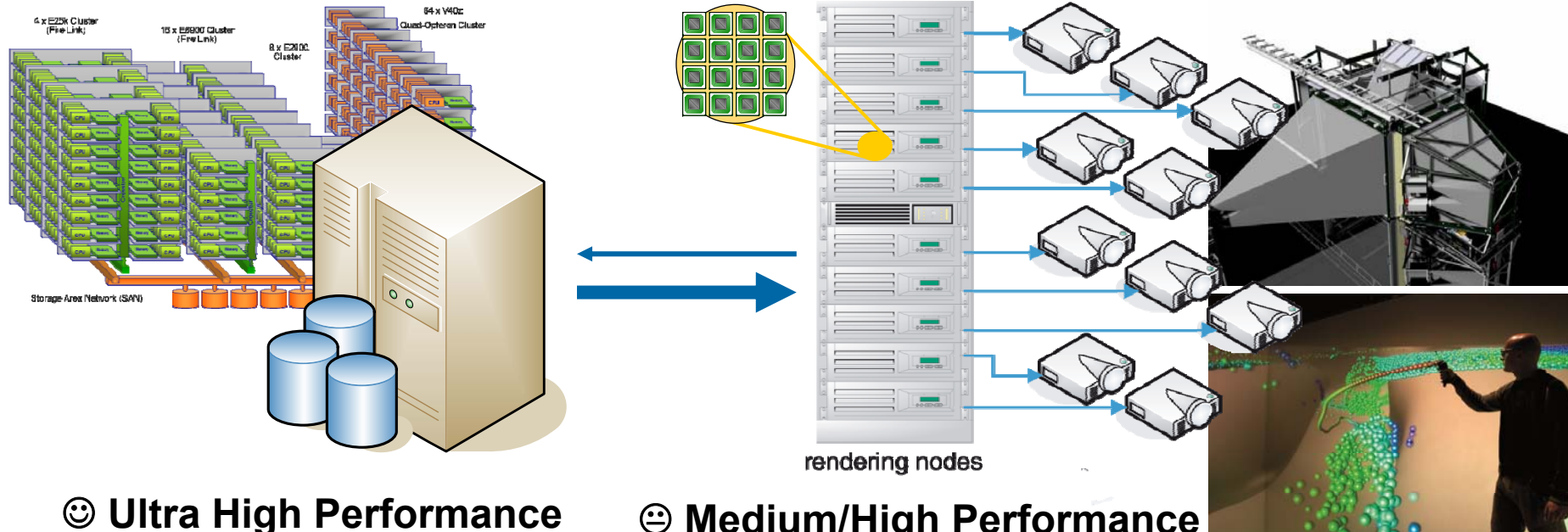
[IEEE 2005, SIGGRAPH 2005 Poster, C&G 29(1), VMV 2006, MMVR 2007, EGVE 2007]
Prof. Dr. Torsten W. Kienle | Immersive Visualization | WS 2014/15 |
Course on Virtual Reality – Name des Kapitels

Handling Large Data: Regions of Interest



Framework for Interactive FlowVis & More

Marc Wolter et al.



- ☺ Ultra High Performance
- ☺ Large Storage
- ☹ High Latency

- ☹ Medium/High Performance
- ☹ Medium/Small Storage
- ☺ Low Latency/Real-Time

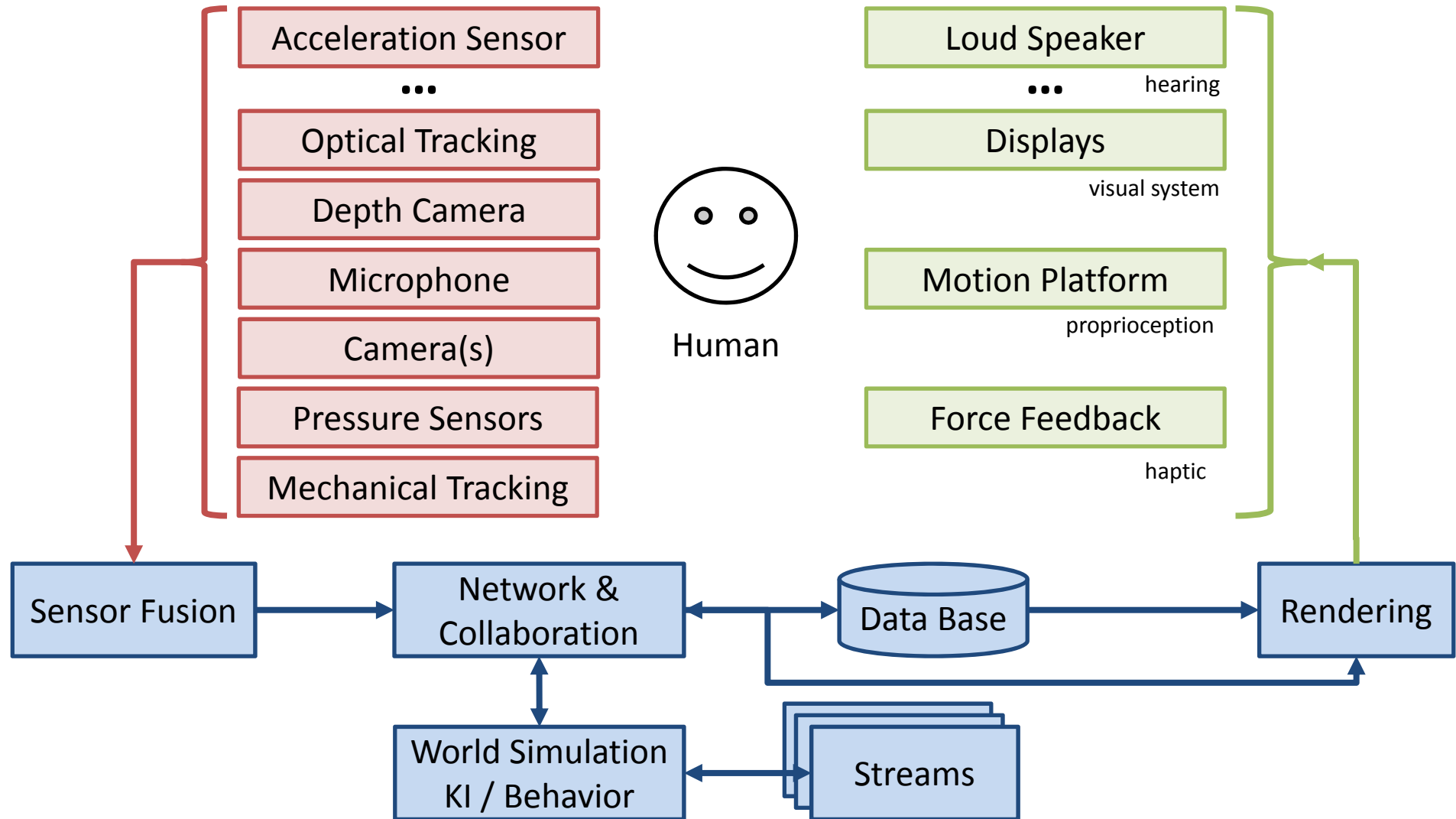
**Large-Scale
Data Processing
(Low- & Mid Frequency
tasks)**

**Interactive Operations
(High Frequency,
Navigation)**

VISTA VIRTUAL
REALITY for
SCIENTIFIC
TECHNICAL
APPLICATIONS

[IMACS 2000, SC 2004, EGVE 2003, EGPGV 2006, SC 2006, EGPGV 2007, ParCo 2007, SEARIS 2008, CGF 28(6)]

VR-Systems



Topics

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- VR Displays and Systems
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